Net neutrality and investment decisions

Comparison of Norway, the EU and the US

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Abstract

This paper examines the topic of net neutrality in a range of countries, with focus on Norway, the US and the EU region. It begins by examining the political settings of each country and by discussing different levels of net neutrality legislation that could be enacted. In the US there is a history of litigious behaviour and anticompetitive practices, and as a result the FCC has reclassified broadband under the telecommunications classification, known as Title II. This reclassification was enacted in order to give greater control to the regulator and be able to enforce stricter net neutrality laws, which expressly forbids blocking, throttling and paid prioritization.

Europe is also strongly pro net neutrality but has a more diverse range of views, owing to the heterogeneity in the European area. Some countries support strict net neutrality, such as the Netherlands, but others, such as Germany, question the financial feasibility of the legislation. Europe also has anticompetitive practices occurring, with evidence suggesting blocking and throttling is occurring across the region.

Norway has the oldest net neutrality doctrine currently in place, and has a strong history of compliance and cooperation between firms and government, and has found success with other regulations of the broadband industry that have failed elsewhere. This is partially due to the coregulatory approach Norway's policy makers use, specifically consulting and taking input from all relevant parties, and also due to the compliance of large companies with the regulatory bodies, which is a stark contrast from the US companies. As would be expected based on this, there is no evidence of the anticompetitive practices examined in this thesis occurring in Norway.

There are also differences in the existing regulation affecting the broadband market in each region. Norway has compulsory unbundling regulation in place, which is forcing any monopolistic network to rent out a portion of its capacity at a competitive price to other providers. This increases competition in the broadband market by subsidising entry and removing the competitive advantage that monopolists have. This policy was originally implemented in the US but was found to be ineffective there. In contrast, Norway and the UK both found it to be effective and plan to continue enforcing it with future networks. Some

areas of the EU implement this policy, while others do not, adding to the heterogeneity of the European markets.

This thesis aims to address three non-neutral strategies discussed in the literature. Firstly, blocking, which is excluding content from the market. Secondly, throttling, which is deliberately degrading the speed and quality of the internet connection for specific content. The third and final strategy is paid prioritization, which is allowing for different tiers of speeds for different prices between the Internet Service Provider (ISP) and Content Providers (CPs). In the current thesis I am using the model from the paper 'The economics of net neutrality' by Economides and Hermalin (2012) in order to examine the issues of blocking, throttling and paid prioritization. The model entails a continuum of CPs and households (HH) connected by a single ISP.

The results show that blocking and throttling unambiguously reduce welfare. Paid prioritization is examined from a welfare perspective, both statically and dynamically under a range of market conditions. Based on this exploration, it is concluded that paid prioritization is welfare maximising in the case of perfect price discrimination by the ISP, while net neutrality is welfare maximising in the case of imperfect price discrimination. Furthermore, ISP investment is reduced by net neutrality, and with perfect price discrimination the welfare effects of net neutrality are ambiguous. The ambiguous final result allows for the possibility of different optimal regulations in each region.

There are several assumptions that are embedded into the model, which temper the strength and realism of the conclusions I have drawn. These assumptions include using a multiplicatively separable preference function, the use of a single ISP, the degree of price differentiation used, and the cost curve selected for the ISP's investment in the dynamic setting. The welfare optimal policy for each country depends crucially on the profits of the ISP compared to the consumer surplus of the HH, and thus depends on the level of competitiveness in the market. This paper then compares each country and concludes that, holding the previous relationship constant across countries, net neutrality laws are more likely to be welfare optimal in the US, while Norway is less likely to have a welfare optimal net neutrality regime.

Foreword

I would like to offer my thanks and appreciation to those who have been integral to both the process of completing this thesis, and in offering me support and advice.

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1 Introduction

1.1 Overview

Net neutrality is a topical economic and political issue, and is about determining the effects of different regulatory approaches to the relationships between Internet Service Providers (ISPs; e.g. Comcast in the US, Telenor, Canal Digital in Norway), Content Providers (CPs; e.g. Google, Netflix, YouTube) and End Users or Households (HH). Although there is no global definition of net neutrality, it generally refers to keeping all internet speed equal rather than having preferential speeds or 'fast lanes' for larger companies, which are feared to lead to anti competitive practices. The name comes from the idea of keeping an internet that is neutral or fair for all parties, with data packets queued fairly and consumers having the same access to all content placed on the internet. The Oxford dictionary defines net neutrality as "The principle that Internet service providers should enable access to all content and applications regardless of the source, and without favouring or blocking particular products or websites" (Oxford Dictionary, 2015). The EU defined it in Amendment 237 recently as: "'net neutrality' means the principle that all internet traffic is treated equally, without discrimination, restriction or interference, independent of its sender, receiver, type, content, device, service or application" (European Commission, 2014a).

Net neutrality is an important issue because of the increasingly important role the internet plays not only in commerce and the global economy, but also in the consumption of goods and services by individuals on a daily basis. Internet accessibility has grown steadily around the globe and there are still areas with potential for high growth in Africa and Asia, where relatively low proportions of the population have access to the internet at 16% and 32% respectively, compared with Europe's estimate of 75% (International Telecommunications Union, 2014). Data consumption is also predicted to continue with exponential growth as more services are substituted from newspapers and television to internet services, as the internet supplants traditional media (European Commission, 2014b). The internet is becoming more and more integrated into people's everyday lives, with 65% of Europeans using the internet daily in 2014, a significant increase from 31% in 2006 (European Commission, 2014b). Data storage is also being shifted online with both large companies and consumers transferring from secure in-house servers to secure cloud-based technology, with more than one fifth of individuals in Europe using cloud based storage systems (European

Commission, 2014b). The European Commission for Digital Agenda predict that overall IP traffic will quadruple by 2016 (European Commission, 2015). They also state that congestion is exacerbated by insufficient broadband coverage in Europe, stating that only half of the investment required for complete coverage by 2020 has been reached (European Commission, 2015). Norway compares well with the world and European averages, with 88% of households having access to broadband and 22% having access to fibre optics (Statistics Norway, 2014).

These growth trends emphasise the importance of finding a clear consensus on net neutrality. Advocates for removing net neutrality argue that the necessary income streams of ISPs required for the next generation of internet infrastructure can only be realised with the ability to charge CPs (Buckley, 2014; Krämer, Wiewiorra, & Weinhardt, 2013; Kushnick, 2014). On the other hand, its defenders raise issues with anticompetitive practices and entry deterrence, as well as pointing to investments in content as a possible casualty of its removal (Gans, 2014; Krämer et al., 2013; Lee & Wu, 2009; Wang, Ma, & Chiu, 2014). This issue is pressing because of the implications it has for investment decisions of ISPs in the future. Internet infrastructure is costly and since 1996 more than $1.3 trillion USD has been invested in broadband by the US industry alone (USTelecom, 2015a). The next generation network will involve direct fibre optic lines into each household. Fibre optic lines allow broadband speeds of up to 1GB per second, which is substantially faster than alternatives. Fibre is also a resilient network as it has the capacity to support broadband speeds of over 1000 times current levels (Broadbandnow, 2015).

The main drawbacks of fibre optic networks are that they are prohibitively expensive. Telenor announced in 2013 an estimated four billion Norwegian kroner investment per year across all of their networks, with the majority of this being put towards the next-generation high-speed internet lines of fibre optics (Telenor, 2015). Verizon has halted expansion of its FiOS (Fibre Optic Services) network, which is fibre optics directly into the household. They reasoned that the investments required per household were making it financially unviable, stating that they had already invested $24 billion in the expansion since 2004 (Buckley, 2014). They further stated that they would need to break even on the initial investment before further expansion could be considered (Buckley, 2014). According to reports, Goldman and Sachs estimate that it would cost $140 billion in order to reach every household in the US with fibre (Yarow, 2012). Given the substantial sums and commitment these investments require, it is imperative that a clear, decisive, and consistent decision is reached quickly, in order to prevent uncertainty from stifling growth. It is equally important that the decision reached is the correct one in terms of maximising the welfare of society, which regulators exist to protect.

1.2 Degrees of net neutrality

Net neutrality is often discussed in binary terms, and political figures and companies are usually framed as being either pro or anti net neutrality. However, it would be more accurate to view it as a continuum of possible policies, with the most pure neutrality at one end and no regulation or oversight at the other extreme. One technique that can be used by ISPs that affects CPs and consumers is throttling, which is the deliberate degradation of traffic quality by use of inefficient information paths. It is feared that throttling can be used to either extract rent from content providers for reaching clients, or to promote a singular product that has paid for the privilege (European Commission, 2015).

A similar concept is blocking, which refers to actively blocking certain content from reaching customers via their network in order to provide exclusivity for a preferred partners product, or extract a 'toll booth' rent from content providers (European Commission, 2014a, 2015). It is important to note that ISPs such as Comcast, AT&T, and Verizon are all against these practices, and these activities would fall under competition law in many countries (AT&T, 2012; Comcast, 2014; Verizon, 2014). However, as will be discussed below, there seems to be some evidence that Comcast has used throttling as a leverage tactic in bargaining with Netflix (Ehrenfreund, 2014).

The next degree of neutrality that has been more central to debate is that of paid prioritisation, which is allowing ISP services to offer higher speed or prioritised traffic at a higher price[1]. Some argue that this would allow for higher levels of investment and a faster, higher quality internet for all, while allowing content providers that rely on streaming or other bandwidth intensive products to offer a more stable and consistent service to consumers (Devins, 2014). Others believe that creating fast lanes for some content must necessarily degrade quality for the slow lane products (Gustin, 2014).

[1] Paid prioritization is also referred to as tiering. In this thesis I also will sometimes refer to a policy involving paid prioritization as a non-neutral regime for convenience.

It is also possible to prioritise data not based on higher payments or its sender, receiver, or the content it holds, but only based on its type. This is known as data discrimination and is considered to be less of a violation of net neutrality than paid prioritisation, as many view it as necessary and efficient network management. Wu (2003) argues that a full neutrality doctrine does not actually treat all content fairly, as it implicitly favours data that requires lower quality connections to consume effectively. As an example, voiceIP and streaming have stricter requirements on quality of broadband and real time delivery, in order to be feasible, compared with other services. Wu (2003) proposes that ISPs should be able to make reasonable decisions in promoting some data in order to lead to a higher quality product overall for consumers . Much of the debate on this issue in the political spectrum is focusing on how much discretion ISPs should be afforded and what constitutes reasonable traffic management (European Commission, 2014a).

Full net neutrality thus entails that all data packets are treated equally, regardless of data type, and this is the strongest of the possible net neutrality regulations. All of the above practices would be illegal under this regime. Opponents to this complete regulation argue that it restricts the ability of ISPs to efficiently manage the network and that it leads to inefficient outcomes (Comcast, 2014; Telenor, 2014).

1.3 Political situation

1.3.1 USA

In the US, the FCC (Federal Communications Commission) is the regulator of telecommunications, including broadband internet. The level of regulation has been legally contested and the newest laws in place will likely be challenged in the courts to determine the enforceability of any such act (Mashables, 2015). Prior to 2010 there had been no explicit regulation in place although the market had operated in a de facto neutral state. To ensure the continuation of this, the FCC released the Open Internet Order, which contained four main principles; transparency, no blocking, no unreasonable discrimination and reasonable discretion for network management. However, in early 2014, the US Court of Appeal for the District of Columbia struck down the discrimination and blocking rules while upholding the transparency rules (USTelecom, 2015b). Possibly as a result of this ruling, in March 2014 the FCC proposed a more expansive regulation, seeking to reclassify broadband under the common carrier rules originally intended for the landline sector, known as Title II (FCC, 2015). The FCC opened up for public opinion on this issue and received over four million responses, most of which expressed either favour for net neutrality or concern at the possibility of erosion of net neutrality (FCC, 2015).

President Obama recently came out in support of net neutrality stating that “An open Internet is essential to the American economy, and increasingly to our very way of life” (Obama, 2014). He also raised concerns about some of the potential negative effects failing to enshrine net neutrality would have on competitive entry, censorship, investment and innovation in technology (Obama, 2014). He called on the FCC to implement the strongest possible rules in order to preserve competition, and expressed concern at allowing ISP services to warp competition and prevent entry in the CP market. He then concluded by emphasising the FCC’s mandate to promote competition, innovation and investment and stressed the importance of net neutrality to this (Obama, 2014).

Comcast and other ISPs have applauded pro neutrality stances taken in the US, however they argue that this does not require the reclassification of broadband services under Title II (Comcast, 2014; Verizon, 2014). Comcast’s EVP David Cohen stated that Comcast is strongly in support of FCC placing legally enforceable rules in place to protect an open internet, even mentioning the need for transparency and reiterating their stance against blocking and discrimination. However, he continued on to say that they do not support a reclassification to a telecommunications service and cited innovation and investment as two victims of this potential move (Comcast, 2015). The Title II reclassification would allow a much larger amount of regulatory control for the FCC, even theoretically allowing them to set price caps, although the FCC has claimed that many of the additional abilities will be disregarded in the new legislation (Comcast, 2014; FCC, 2015; Wheeler, 2015).

On February 5th 2015 the FCC announced its proposal for reclassifying broadband under Title II, which reinstated the bans on blocking, throttling and paid prioritisation, while also giving themselves authority to address complaints about ISP practices (FCC, 2015). The FCC also stated that there would be no rate regulation, no last-mile compulsory unbundling and no additional administrative requirements that other industries face under Title II (FCC, 2015). They also believe they will be able to foster sufficient investment, citing as an example the wireless industry, which has been under Title II and has healthy levels of investment (FCC, 2015; Wheeler, 2015). On February 26th 2015, the FCC passed these regulations into law, formally reclassifying broadband under Title II. FCC chairman Tom Wheeler underlined the significance of the new regulations, stating that "The Internet is simply too important to allow broadband providers to be the ones making the rules", while opponents indicated that this ruling would definitely be challenged in the legal system (Mashables, 2015).

Net neutrality graduated from a theoretical fear to a practical issue when some ISPs were reported to be intentionally throttling during a negotiation period with select CPs. The Washington Post reported that Comcast was throttling Netflix data, which significantly lowered the quality of their product, in order to extract extra rent from them (Ehrenfreund, 2014). This was the type of rent extraction advocates for net neutrality have feared, as it can allow for entry deterrence for a premium by degrading competitors' quality, or by just raising the capital required to enter the market. There is also evidence that throttling and blocking occur in Europe, as the Body of European Regulators for Electronic Communications (BEREC) discovered in a fact-finding mission released in May 2012 (BEREC, 2012). Netflix and other CPs have unsurprisingly come out heavily in favour of strong net neutrality, with Netflix CEO Hastings stating clearly that it is the ISP's responsibility to pay for the network (Hastings, 2014). Both the CP industry and the ISP industry have vested interests in the outcome of this debate. CPs would enjoy higher profits if the concept of net neutrality were enshrined, as it protects them from exposure to rent seeking behaviour from ISPs. In contrast, ISPs would prefer more relaxed net laws, as stricter versions will restrict their ability to adequately charge CPs for the network they build and provide.

1.3.2 Europe

The political landscape in Europe is much larger and more heterogeneous in comparison with the US. Overall, the EU has taken a very pro net neutrality stance, with the EU commission passing a bill on net neutrality regulation via many amendments that passed their first vote in April 2014. The European Commission responsible for the Digital Agenda does acknowledge the need for some data discrimination. They specifically note that certain services and applications require some degree of prioritisation to offer a reasonable product and experience to consumers (European Commission, 2014a). Not all areas of Europe share the same views, however. One of the most pro neutrality countries is the Netherlands, which was the first European country to enshrine net neutrality into law in 2012 (Berners-Lee, 2015).

More recently, Germany's Chancellor, Angela Merkel, made statements in contrast to the EU position stating that while an innovation friendly internet is important, the development of this relies on the network offering reasonable and predictable quality of service (Devins, 2014). The real question of how strong the net neutrality legislation is going to be, and how heavily it will be enforced, will only become clear in practice over time.

1.3.3 Norway

Norway has the oldest net neutrality policy in Europe currently in place (Sørensen, 2014b). The issue has not received the same level of airtime as in the EU parliament, or within the US and, as a result, is not as hotly debated. That may be attributed to Norway being relatively unique as one of the only countries to adopt a coregulatory approach, where the government acts as a mediator rather than a warden of the market place. This method facilitates discussion and compromise between all interested parties. Norway, along with the rest of Scandinavia, have a high degree of cooperation from ISPs and CPs. Norway's ISPs have a history of being extremely compliant and this contrasts with the litigious nature of the relationship between regulator and ISPs in the US (Kushnick, 2014; Mashables, 2015). In Norway, the regulator is The Post and Telecommunications Authority (NKOM), which has taken a pro net neutrality position (Sørensen, 2014a, 2014b). NKOM dismissed concerns about the profitability of ISPs, noting that it is the ISPs themselves that choose a flat pricing model for consumer internet access (Sørensen, 2014a). NKOM defended their position by stating that it is online content that drives the demand for ISPs products, and that the demand for higher bandwidth intensive content is beneficial for both parties (Sørensen, 2014a, 2014b). They also stressed that the network effects of increasing the number of users increase the value of the content or applications they use (Sørensen, 2014a).

However, while being pro neutrality and against paid prioritization, NKOM is not against data discrimination, noting that the most important goal of net neutrality regulation is to preserve an open internet and prevent discrimination and fragmentation[2]. They also state that this requires some degree of reasonable network management (Sørensen, 2014a, 2014b). NKOM opted for a coregulatory approach, in which all affected parties are involved in the decision making process and guidelines are put in place that are followed in good faith. This is only possible due to the compliance of stakeholders in Norway, and removes the need for

[2] Fragmentation in this context refers to concerns that rampant blocking and other anticompetitive practices could lead to several smaller 'internets' rather than the single unified internet that currently exists.

laws to be put in place or for the courts to make rulings, such as in the US.

In 2009, NKOM coordinated an agreement intended to enshrine net neutrality by brokering an internet services agreement with Norway's relevant major ISPs, the Consumer Council of Norway (CCN; Forbrukerrådet) and some representatives from the IT community (Sørensen, 2014b). The agreement was based on three principles. Firstly, that end users be given complete and accurate information on the quality and capacity of the internet they are purchasing. Secondly, that users should be allowed to send and receive any content with no restrictions, and be free to choose any services or applications, provided they do not hurt the network. Thirdly, that connections cannot be discriminated against on the basis of content, receiver, sender, or application choice (Forbrukerrådet, 2011). The overarching theme to the agreement in the words of Thomas Nordvedt, Head of Section Digital Services at the Consumer Council of Norway (CCN; Forbrukerrådet), was that "It must be up to individual broadband customers to decide how to use their bandwidth" (Forbrukerrådet, 2011). NKOM made it clear that it was expected that even companies that did not endorse the guidelines must still adhere to them (Sørensen, 2014b). However, Telenor, one of the largest ISPs in Norway, withdrew from the agreement in 2011(Forbrukerrådet, 2011). Telenor stated that they now believed that internet and mobile users should pay for data travelling through their network, and pointed to substantial increases in traffic over recent years. They further claimed that the current business model was financially unsustainable, and announced plans to charge YouTube and NRK for content streaming (Forbrukerrådet, 2011). CCN condemned this decision, describing it as disappointing and "a step in the wrong direction" (Forbrukerrådet, 2011).

NKOM holds annual meetings in order to discuss issues facing the industry. These meetings are attended by concerned parties and stakeholders. In late 2013, one such meeting was held that focused on the European Commission's recent net neutrality initiative[3] (Thorkildsen, 2014). During this meeting, Telenor stated that while some elements of the initiative were good, restricting the ISPs ability to prioritise traffic and manage the network would ultimately harm the consumers. They also expressed concern that further regulations from the EU government would be too restrictive on both the industry and their customers (Telenor, 2014). They concluded that they were happy with the current net neutrality guidelines in

[3] The meeting occurred on the 10th of October 2013 and participants included NKOM, CCN, NRK, TV2, Cable Norway and other stakeholders.

Norway. In March 2014, Telenor's division director Harald Krogh criticised the efforts of the EU parliament, saying that what started as an effort to maintain a free and open internet had turned into a mechanism that could stifle innovation and degrade the quality of the internet for everyone (Telenor, 2014). He stressed that every ISP has strong incentives to keep the internet free and open, as internet access is their core product and they have no incentives to degrade the quality of service (Telenor, 2014). He referenced the large continuous investment Telenor makes in its infrastructure and noted that the only content they censor is illegal material such as child pornography, copyright violations, or intellectual property rights violations[4]. He then went on to criticise the vagueness and room left for interpretation in the current EU regulation and sighted inefficiencies in some of the possible interpretations of the rules (Telenor, 2014).

In March 2014, it was reported by Dagbladet that Telenor and Netflix had reached a private agreement to host Netflix servers on Telenor's networks for an undisclosed amount, weeks after Netflix made an agreement with Comcast (Thorkildsen, 2014). CCN's comment in the article described it as troubling, whereas Telenor responded that no net neutrality principles were being violated. Telenor stated that this deal involved caching, which is storing data on the Telenor network, which they described as part of expanding the network's capacity (Thorkildsen, 2014). NKOM stated that they considered the use of caching acceptable as long as it was not to the detriment of other traffic, however, caching methods or systems would not automatically be considered net neutral and would be considered individually (Thorkildsen, 2014). Concerns were also raised about the conflict of interests that can arise for ISPs. The fear was that when they have a competing product in the market, they would have incentives to influence the quality of competitors' products via their network management. More specifically, concerns were raised in the media regarding Telenor's control over Spotify's traffic, as they were directly competing with their own product WIMP (Forbrukerrådet, 2011).

[4] Both intellectual property and copyright infringements are dealt with in the legal system and ISPs simply follow directives from the courts.

1.4 Regulatory measures

1.4.1 Compulsory unbundling

Compulsory unbundling[5] is one of many regulatory measures available to create competition in sectors that have natural barriers to entry. Compulsory unbundling refers to forcing a monopolistic network operator to rent out a portion of their network to competitors at a price set by the regulator, in order to create a sufficient level of competition (Wallsten & Hausladen, 2009). It is generally accepted by both sides of the debate that reasonable levels of competition in the industry mitigate net neutrality concerns to some degree (Wallsten & Hausladen, 2009). Compulsory unbundling is a mechanism to maintain sufficient competition in markets where building parallel systems and infrastructures are prohibitively expensive and inefficient, broadband is a network that falls under this umbrella. This facilitates entrance to the retail market, as a regulated price must necessarily be less than the price offered to consumers, and allows potential entrants to enter the market. Entrants capture a share of the market by offering a price above the regulated price but below the current market prices. In this way competition is increased, monopolistic power is weakened and consumer surplus is increased (Wallsten & Hausladen, 2009). Compulsory unbundling has occurred previously in the US, Europe, New Zealand, Japan and South Korea in the telecommunications markets for phone lines and broadband (Crandall, Eisenach, & Ingraham, 2013).

In the US, local or large scale monopolies of phone and power lines (and more recently broadband connection) are commonplace. Rather than using compulsory unbundling to artificially increase the level of competition in a market, the preferred current method of protecting consumers is with a large degree of regulatory oversight (Crandall et al., 2013; Wallsten & Hausladen, 2009). Compulsory unbundling originated in the US in 1996. The prevailing theory motivating this was that it would lead to higher competition in the short term, and once market shares were established, entrants would invest in their own infrastructure and expand the size of the networks (Wallsten & Hausladen, 2009). However, what was observed was that the low regulated price disincentivised firms to invest, and firms instead chose to continue to use the low cost network of the incumbent (Wallsten & Hausladen, 2009). In more recent times, the US tends to emphasise competition between networks rather than within networks, and no longer requires new telecom networks to

[5] Compulsory unbundling is also referred to as mandatory unbundling generally, or when specifically talking about broadband often referred to as Local Loop Unbundling or LLU.

unbundle (Wallsten & Hausladen, 2009).

Aggregate data across countries has typically shown a negative effect of unbundling on investment. This finding is intuitive as unbundling weakens investment incentives because the benefit of building a next generation network is lessened (Wallsten & Hausladen, 2009). Wallsten and Hausladen (2009) contend that compulsory unbundling may not necessarily change incumbent network operators' incentives to prioritise or affect traffic. Unbundling in the UK has shown different results; Nardotto, Valletti, and Verboven (2014) found that unbundling significantly increased entrance into the market and increased overall broadband penetration. The increased broadband penetration suggests that the effect on investment incentives was outweighed by the effect of increased competition. Nardotto et al. (2014) observed significantly faster download speeds and concluded that unbundling leads to higher quality of service to consumers. This contrasts Wallsten and Hausladen's (2009) conclusion, which is that countries that rely on unbundled networks see less investment in next generation networks. They contend that as a result, higher competition between networks is more effective than higher competition within networks at increasing investment. Furthermore, there is evidence to suggest that the effect on fibre deployment and investment could well exceed the effect on the last generation of networks, due to the timing of the regulation (Crandall et al., 2013). Copper networks had already been built, and the investments sunk, before unbundling was announced originally. Crandall et al. (2013) suggests that unbundling would likely deter the deployment of the fibre network entirely, and thus harm consumer welfare.

Norway has previously turned to compulsory unbundling to regulate DSL (Digital Subscriber Line) networks. In 2000, Telenor was the incumbent operator of the older generation ADSL (Asymmetric DSL) network, which the new entrant NGT devalued by expanding a newer DSL network. Norway's previous unbundling regulations have been accepted with no resistance from large ISPs (Telenor, 2013). NKOM determined that the price set was too high and in response Telenor, the ISP owning majority of the copper lines, offered to reduce the rental price a further 15%. It was reported in 2014 by ZDnet, a technology publication, that NKOM has determined that Telenor's fibre wholesale network will now be required to allow LLU (Øyvann, 2014).

1.4.2 Regulatory oversight

Regulatory oversight is a more straightforward measure available to regulators. Typically, this entails enshrining net neutrality into law and explicitly defining acceptable and unacceptable business practices. This also requires a regulatory watchdog that monitors market participants to prevent indiscretions and to enforce punishments, litigation or resolutions in the case of violations. This is the enforcement measure currently being used and considered in Europe and the US. The degree of oversight should be related to the level of compliance from market participants and the prevalence of anticompetitive practices.

1.4.3 Regulation's effect on competitiveness

Industries that involve public goods, such as broadband, have always been regulated to some degree. It is difficult to tease apart the effects of this base level of regulation from the intrinsic elements of the market. Is broadband a naturally monopolistic market, or has the existing regulation and municipal governance of the industry dissuaded entry and led to this result? Kotrous (2015) argues that the market for broadband is overly regulated at the local ISP level, and that this reduces entry and competition, and facilitates higher levels of market power. He argues that this market power is the very symptom net neutrality advocates are trying to restrict with net neutrality laws, but states that a better solution would be to remove the existing municipal regulations which act as an entry deterrence. Kotrous (2015) then concludes that less regulation, in the form of removing barriers to entry, is a less convoluted and more logical solution to the issue, rather than applying additional regulation in the form of net neutrality laws. This however, does not address some underlying issues that occur in network economics and in strategic competition settings. Given the fixed costs and marginal costs implied from building and forming a network, it is clearly possible to have a socially inefficient amount of entry, both in terms of too much or too little (Tirole, 1988). There are also network effects occurring in this setting as more competition via easier initial entry also lowers investment incentives, so the validity and realism of deregulation improving social welfare remain unclear.

1.5 Focus questions

1.5.1 Motivation for research questions

Net neutrality is a broad and diverse topic of interest and as such there is a wide range of models and focus questions in the literature. The focus of this thesis will be on the welfare of society under different regimes, and I will examine a range of issues.

One of the areas of interest for this thesis is blocking. Blocking is worth investigating, as it is an action that is publicly dismissed by all parties, but there is evidence to suggest that it has occurred across multiple countries. Therefore, a focus will be to investigate the welfare effects of blocking to determine whether it is an issue that warrants legislative focus, and whether its effect is positive, negative or ambiguous. Similarly, throttling has been shown to occur both in the US and in Europe so its welfare effects are important to examine.

However, as the introduction shows, paid prioritization is the most ambiguous issue currently facing policy makers, and its welfare effects in previous literature have been the most diverse and unclear. Therefore, this issue warrants clear attention and will be a large focus of the following analysis. While there is a large body of work surrounding static welfare with a fixed supply of bandwidth, an area warranting more focus is the dynamic effects on infrastructure investment of ISP's. Thus, an important research questions for us to address is the welfare effects taking into account future investments, and the net effect of different regimes on future investment. This thesis will aim to discuss possible regulatory regimes in conjunction with existing regulation and market conditions in each region. Therefore, it is important to investigate whether the net neutrality is welfare maximising unambiguously, or whether the optimal regulatory regime can vary between countries and regions.

1.5.2 Model selection

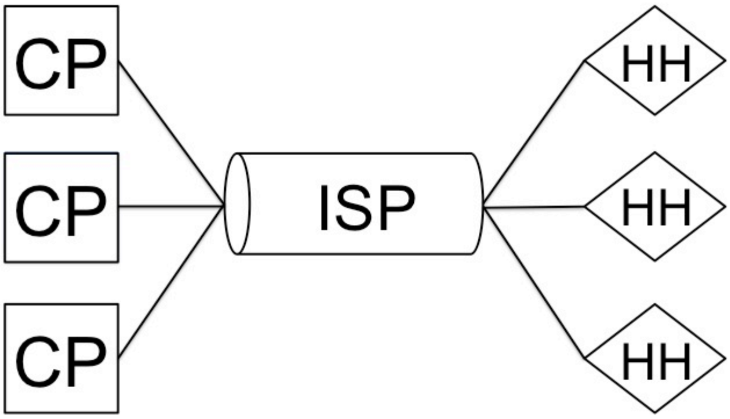
The model I have selected is from Economides and Hermalin (2012) from the RAND Journal of Economics, titled “The economics of net neutrality”. There are multiple motivations for my model selection; 1) The model needs to be tractable in order to allow me to analyse the results. At the same time it needs to be concise enough that reasonable conclusions can be gleaned from it. 2) The model needs to address all aspects of the research questions posed in the introduction. More specifically, the model needs to address welfare effects of non-neutral strategies, like blocking and throttling, the welfare effects of prioritization, and the dynamic effects regimes have on investment and future welfare.

2 Model

2.1 The Structure of the game

This model involves 3 different agents: Content Providers (CP) who produce content for household consumption, Households (HH) that consume content from CPs, and a single Internet Service Provider (ISP) that intermediates the exchange by connecting the two. Figure 1 shows the interactions between players in this model.

Figure 1. Conceptual model



The ISP servers have a total bandwidth capacity of B, which is the maximum content that can be transferred to households. The ISP is a monopoly which divides the bandwidth across sub bandwidths, such that $B_1, B_2, \ldots\ldots\ B_n$ where n is the number of sub-bandwidths selected.

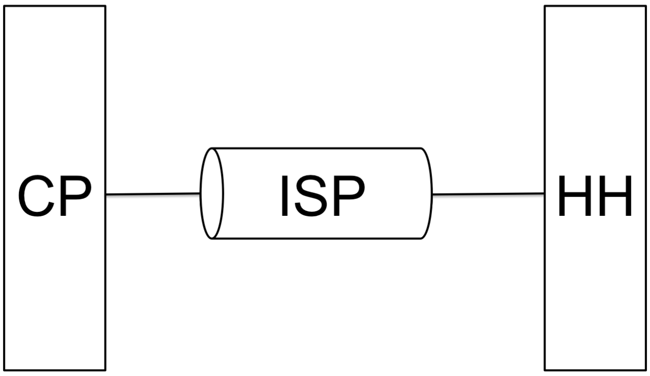
Content providers are on a continuum $[\underline{\theta}, \overline{\theta})$ that has a distribution $F(\underline{\theta}, \overline{\theta})$ which approximates *F(0,1). F' >0 for all* $\theta \in [\underline{\theta}, \overline{\theta})$. *x(θ)* is the units of content supplied by a given content provider (θ). Let Q_i be a subset of CPs such that $Q \subset [\underline{\theta}, \overline{\theta})$ with dedicated bandwidth of B_i. Given this, t is the time required to send all content for all providers in the set such that

$$t(Q_i) \equiv \frac{\int_Q \ x(Q_i) dF(Q_i)}{B_i} \tag{1}$$

This shows that the total time required is the content for each CP in the set, integrated over its pdf and divided by the total bandwidth allocated to the set. $x(Q_i)$ is the demand for content in set Q_i. $t(.)$ is a measure of congestion faced by content providers and $t(Q)$ is the measure of congestion for those in set Q. $\tau(\theta)$ will be used to denote the congestion faced by individual Content Providers, note that if $\theta \in Q$ then $\tau(\theta) = t(Q)$.

There is also a continuum of consumer households (see figure 2 for a schematic representation).

Figure 2. Schematic model



HH utility is quasilinear and additively separable with respect to content from different providers. HH are also homogenous in preferences, with *m'<0 and m''<0*. HH marginal utility is

$$m\left(\frac{x}{\alpha(\tau(\theta), \theta)}\right) \tag{2}$$

for the *x*th unit of content from content provider θ. $\alpha(\tau(\theta), \theta)$ is an adjustment factor, which accounts for the congestion in transmission, the value of that content to the households, and the households' preferences regarding congestion for that content. We impose limitations on the convexity of the marginal utility, assuming that for any A, $Am''(A) + m'(A) < 0$ in order to rule out infinite solutions in later calculations.

Household utility function can now be expressed as

$$U = y + \int_{\underline{\theta}}^{\overline{\theta}} \left(\int_0^{x(\theta)} m\left(\frac{x}{\alpha(\tau(\theta), \theta)}\right) dx \right) dF(\theta) \tag{3}$$

where y is consumption from non internet goods and *x(θ)* is the consumption of the θth content provider's good. We assume that $y > 0$ so that the household never consumes its entire income on content and internet access.

We also impose the assumption that, all else held equal, households prefer less congestion and thus faster delivery to slower delivery. We also assume that higher θ content is more time sensitive to consumers. These are shown in conditions
(4) and (5).

$$\tau > \tau' \rightarrow \alpha(\tau(\theta), \theta) < \alpha(\tau'(\theta), \theta)\ \forall\theta \tag{4}$$

$$\alpha(\tau(\theta), \theta) - \alpha(\tau'(\theta), \theta) < \alpha(\tau(\theta'), \theta') - \alpha(\tau'(\theta'), \theta') \tag{5}$$
$$\text{given } \tau > \tau', \theta > \theta'$$

Due to the quasilinearity assumption and the unconstrained nature of the content consumption decision, I can manipulate equation (1) to derive the demand function. As marginal utility of the θth CP's content will be equal to the price charged in equilibrium, the resulting demand is

$$m\left(\frac{x}{\alpha(\tau(\theta), \theta)}\right) = p \leftrightarrow \left(\frac{x}{\alpha(\tau(\theta), \theta)}\right) = m^{-1}(p) \tag{6a}$$

$$x(p, \theta) = \alpha(\tau(\theta), \theta)m^{-1}(p) \equiv \alpha(\tau(\theta), \theta)\omega(p) \tag{6b}$$

where $\omega(p)$= $m^{-1}(p)$, that is the inverse of the marginal utility. The equation above (6b) shows that demand for any given CP product at any given price will increase as τ decreases, which is reasonable, as it embodies the preference of consumers for faster content delivery. It also allows for demand to be differently affected for separate content providers. $\omega(p)$ does not vary across content providers and is an unvaried demand curve of sorts, where traditionally we would divide by the number of producers in the market, in this model this is encompassed by the $\alpha(\tau(\theta), \theta)$ function.

When modelling the CP pricing decisions we need to define more variables. q is the advertising rate, c is the marginal cost of production and transmission of the content, and s is the gross payment to the ISP. As above x is the demand function for households and p is the price charged to households. CP profits are given by:

$$\Pi_{CP} = max_p(p + q - c)x(p, \theta) - s \tag{7}$$

Note that $p + q - c$ is the margin per unit of content exchanged. In order to rule out infinite consumption, we impose that $\lim_{p \to 0} \omega(p) < \infty$ and that $p \geq 0$ which both are reasonably realistic. In combination with the convexity assumption we imposed earlier, this is sufficient for a unique solution to exist. By substituting (6) into (7) using demand we can show that

$$\Pi_{CP} = max_p (p + q - c)\alpha(\tau(\theta), \theta)\omega(p) - s \tag{8}$$

As s is exogenous to the strategic pricing decision and $\alpha(\tau(\theta), \theta)$ is independent of price, the problem can be reduced to

$$\pi = max_p (p + q - c)\omega(p) \tag{9a}$$

Let p^* define the optimal price of content, and π is the gross profit factor.

$$\pi = (p^* + q - c)\omega(p^*) \tag{9b}$$

$$\Pi_{CP} = \alpha(\tau(\theta), \theta)\pi - s$$

The consumer surplus is defined as the benefit to consumers when willingness to pay is higher than price.

$$\int_{p^*}^{\infty} x(p, \theta) dp \tag{10}$$

Using the same substitution we made at (9a), we can rewrite this as

$$\alpha(\tau(\theta), \theta) \int_{p^*}^{\infty} \omega(p) dp. \tag{10a}$$

I define the integral as σ, which is the consumer surplus factor, and can thus define total welfare, W, as the sum of CP profit, consumer surplus and *s*, the transfer from CP to ISPs. The last is included as a direct transfer between members of society and does not entail a total welfare loss. Welfare from each individual CP is the amount of content sold, which yields both a profit and consumer surplus, this can be expressed as

$$(\pi + \sigma)\alpha(\tau(\theta), \theta).$$

When summing across the entire set of content providers we find

$$W = \int_{\underline{\theta}}^{\overline{\theta}} (\pi + \sigma)\alpha(\tau(\theta), \theta) dF(\theta). \tag{11}$$

This equation has some intuitive interpretations. All else held equal, welfare is increasing in the profit share per exchange of content providers, and the consumer surplus of households per exchange. This states that if the gains from trade increase, either via lower supply costs or higher valuation of the good provided, or both, then total welfare will increase, ceterus paribus. This equation also shows that all else held equal a lower range of content being exchanged reduces welfare. It also shows that lower transmission times lead to higher welfare. However, content exchanged and transmission times are negatively linked, meaning that excluding content reduces congestion, the net effects of these two on welfare will be explored below.

2.2 Welfare analysis

This section of the model will focus on analysing the welfare under neutral and non-neutral regimes (a non-neutral regime allows for paid prioritization, but does not allow for blocking or throttling behaviour), in some cases looking at specific non-neutral regimes, while in others allowing players within the model to optimise themselves. The purpose of this section is to determine the regimes and conditions that optimise total welfare of the economy.

2.2.1 Relationship between content traded and welfare

In order to extend later analysis, determining the relationship between content and welfare will allow us to determine the welfare effects through the regimes' effects on the amount of content traded. To that end, let $Q_1, Q_2 \ldots Q_n$ denote subsets of $[\underline{\theta}, \bar{\theta})$ and as noted earlier, B is the total bandwidth of the network and can be subdivided and allocated in any way, with *n* CPs in the market, $B_{1\,,}B_2 \ldots\ B_n$ subdivisions occur. In equilibrium we find that

$$t_i = \frac{1}{B_i} \int\limits_{Q_i} x(p^*, \theta) dF(\theta). \tag{12a}$$

This equation states that t_i, delivery time, is inversely related to the size of that specific CP's bandwidth allocation B_i, while increasing in the demand for content from content providers within set Q_i. Making the same substitution used to find equation (6), it can be shown as

$$\frac{1}{B_i} \int\limits_{Q_i} \alpha(\tau_i, \theta) \omega(p) dF(\theta). \tag{12b}$$

As $\omega(p)$ does not vary across the integration, it can be pulled outside the integral. Taking into account that and the optimal pricing decisions of the CP's found in section 2.1.

$$t_i = \frac{1}{B_i} \int\limits_{Q_i} x(p^*, \theta) dF(\theta) = \frac{1}{B_i} \omega(p^*) \int\limits_{Q_i} \alpha(t_i, \theta) dF(\theta) \tag{12}$$

I will start by comparing two different divisions of $[\underline{\theta}, \overline{\theta})$. First $Q_1, Q_2, \ldots, Q_n$, and an alternative $\hat{Q}_1, \hat{Q}_2, \ldots, \hat{Q}_m$, with divisions of B into $B_{1\,,}B_2, \ldots, B_n$ for the former, and

$\widehat{B}_1, \widehat{B}_2, \ldots, \widehat{B}_m$ for the later. Rearranging equation (12) and aggregating across the bandwidth for each division leads to

$$\sum_{i=1}^{n} B_i t_i = X, \qquad \sum_{i=1}^{m} \widehat{B}_i t_i = \widehat{X}. \tag{13}$$

This is to say that the total amount of content sent in equilibrium is equal to the bandwidth allocations multiplied by delivery time and aggregated. Using equation (11) and rearranging it to be a summation of the partitions rather than an integration of the total range yield

$$W = \sum_{i=1}^{N} (\pi + \sigma) \int_{Q_i} \alpha(t_i, \theta) dF(\theta) \tag{14a}$$

We can rearrange equation (12) to find

$$\frac{B_i t_i}{\omega(p^*)} = \int_{Q_i} \alpha(t_i, \theta) dF(\theta).$$

And by substituting this into (14a) and moving constant multipliers outside the summation we get

$$W = \frac{(\pi + \sigma)}{\omega(p^*)} \sum_{i=1}^{N} B_i t_i. \tag{14b}$$

Using equation (13) we can insert total demand for the summation arriving at

$$W = \frac{(\pi + \sigma)}{\omega(p^*)} X. \tag{14}$$

The same calculations can be made with $\widehat{Q}, \widehat{B}\ and\ t_i$ to find the equivalent solution of

$$\widehat{W} = \frac{(\pi + \sigma)}{\omega(p^*)} \widehat{X}. \tag{15}$$

Equations (14) and (15) can be used to show that when comparing the welfare of two different bandwidth partitions or two different states, total content demanded is a sufficient statistic to show higher total welfare. This can also be extended to state that any net neutral regime is welfare dominant to a non-neutral regime if the non-neutral regime leads to a reduction in total content exchanged. A key point that leads to this result is that households must have the same marginal utility across content from different sources. More content has two effects; it allows for more efficient allocations by households, as they are free to substitute consumption within a larger budget set, and it also has a constant positive effect on the profits of CPs.

2.2.2 Blocking's effect on welfare

Using the above result, I now focus on determining what effect blocking has on the total content exchanged, as that result can be extended to examine the effect that the ISP has on welfare when it chooses to block certain content. I start by partitioning the total range of content providers, into $Q_{included}$ and $Q_{excluded}$ where $Q_{excluded} \cup Q_{included} = Q_{total}$. For blocking to be welfare enhancing, total volume of content exchanged must be larger with blocking compared to without blocking. Denoting these with $X_{blocking}$ and $X_{neutral}$, with subscripts referring to blocking and neutral regimes respectively. $X_{blocking} \geq X_{neutral}$ implies that blocking is weakly welfare superior while $X_{blocking} \leq X_{neutral}$ implies that blocking reduces total welfare. Following this we use $t_{blocking}\ and\ t_{neutral}$ to denote the transmission times under the two regimes. From the definition of t

$$t_{blocking} = \frac{X_{blocking}}{B}$$

and

$$t_{neutral} = \frac{X_{neutral}}{B}.$$

Using proof by contradiction, assume that

$$X_{blocking} \geq X_{neutral}.$$

Given this, it is clear that

$$t_{blocking} \geq t_{neutral}.$$

Hence, given the negative effect of t on $\alpha(t(\theta), \theta)$

$$\alpha\left(t_{blocking}, \theta\right) \leq \alpha(t_{neutral}, \theta).$$

Using (12) and (13) I find that

$$\omega(p^*) \int_{Q_{included}} \alpha\left(t_{blocking}, \theta\right) dF(\theta) < \omega(p^*) \int_{Q_{total}} \alpha(t_{neutral}, \theta) dF(\theta)$$

However, this gives the conclusion that

$$X_{blocking} < X_{neutral}$$

This is a proof by contradiction, as above it was assumed that blocking leads to higher amounts of content traded. Intuitively, this proof hinges on the fact that the $Q_{included}$ is a subset of Q_{total} and thus contains strictly less content. Transmission times necessarily increase with more content being traded, so in order for more content to be traded in equilibrium the transmission time must be higher than in the regime where less content is traded. Therefore, all that blocking achieves in practical terms is to lessen the households feasible set, as households now have strictly less content providers to smooth between. It also lowers the total profits of the CP market by excluding positive profits for some content. So blocking lowers both the total profits of CPs and the consumer surplus of HH, unambiguously reducing total welfare.

This and the earlier results are sufficient to conclude that blocking is welfare reducing, as it lowers total content exchanged. It is important to this result to note that I have implicitly assumed that the blocking regime does not prioritize traffic, and that all data within the $Q_{included}$ subset is treated equally. This is to isolate the effect of blocking from that of prioritization of data.

It is also worth noting that this result for blocking implies that throttling must also be welfare harming, as throttling leads to higher transmission times and does not entail a transmission time reduction for other content. Thus, this can only serve to reduce consumption of those contents that are throttled and causes consumers to reoptimise to other content, which by definition must reduce welfare[6].

2.2.3 The welfare effects of prioritization

In order to examine the welfare effects of prioritization, the net effect of the preference function on different types of content providers must be determined. This is because in order to tease apart whether total welfare is increasing or increasing with reallocations of bandwidth to different content providers, the cross-partial derivative with respect to transmission time and content type must be examined. Intuitively, because the preference function depends on both the type of content, and the transmission time for a given content, the relationship between the two determines how different regimes affect welfare. To examine this, first the bandwidth constraint must be calculated. The bandwidth used by any given content provider θ is the total demand for θ content divided by the transmission time for that content[7]. Therefore the bandwidth used by θ content is

$$\frac{x(\theta)}{\tau(\theta)} dF(\theta) \tag{15a}$$

Aggregating this over the entire range of content gives us the total bandwidth constraint

[6] If degrading transmission times on specific content has no effect on consumer surplus and total welfare, then said content must have not been consumed at all in the previous equilibrium.

[7] As there is a continuous range of content and content providers, it is simpler to consider each content provider as providing a specific content, although it is not necessary or required.

$$B = \int_{\underline{\theta}}^{\overline{\theta}} \frac{x(\theta)}{\tau(\theta)} dF(\theta) \tag{15}$$

Using equation (6), substituting out demand, and rearranging leads to

$$B = \omega(p^*) \int_{\underline{\theta}}^{\overline{\theta}} \frac{\alpha(\tau(\theta), \theta)}{\tau(\theta)} dF(\theta). \tag{16}$$

I will now use a Lagrangian solution to the constrained optimization of welfare subject to the bandwidth constraint. Starting with equation (11)

$$W = \int_{\underline{\theta}}^{\overline{\theta}} (\pi + \sigma)\alpha(\tau(\theta), \theta) dF(\theta) \tag{11}$$

and the constraint

$$B = \omega(p^*) \int_{\underline{\theta}}^{\overline{\theta}} \frac{\alpha(\tau(\theta), \theta)}{\tau(\theta)} dF(\theta). \tag{16}$$

In Lagrange form the problem of maximizing welfare becomes

$$\mathcal{L} = \int_{\underline{\theta}}^{\overline{\theta}} (\pi + \sigma)\alpha(\tau(\theta), \theta) dF(\theta) - \lambda\left(\omega(p^*) \int_{\underline{\theta}}^{\overline{\theta}} \frac{\alpha(\tau(\theta), \theta)}{\tau(\theta)} dF(\theta) - B\right), \tag{17}$$

where λ is the multiplier on the constraint. Simplifying this expression we arrive at

$$\mathcal{L} = \int_{\underline{\theta}}^{\overline{\theta}} \alpha(\tau(\theta), \theta)(\pi + \sigma - \frac{\lambda(\omega(p^*)}{\tau(\theta)}) dF(\theta).$$

Maximizing this function for each θ with respect to $\tau(\theta)$, is akin to maximizing

$$\alpha(\tau(\theta), \theta)\left(\pi + \sigma - \frac{\lambda(\omega(p^*)}{\tau(\theta)}\right).$$

The second term is positive (Economides & Hermalin, 2012). Given this, and that maximization solutions do not vary across log transformations, $\tau(\theta)$ must also maximize

$$\log\big(\alpha(\tau(\theta), \theta)\big) + \log(\pi + \sigma - \frac{\lambda(\omega(p^*)}{\tau(\theta)}) \tag{18}$$

We assume an interior solution exists. How the optimal $\tau(\theta)$ varies across θ depends on the cross-partial derivative of (16) with respect to θ and $\tau(\theta)$. If it is positive, then optimal $\tau(\theta)$ is increasing in θ. If it is negative, then optimal $\tau(\theta)$ is decreasing in θ. If it is constant then there will be a single optimal $\tau(\theta)$ for all θ.

The sign of this equation will be the sign of the term $\log\big(\alpha(\tau(\theta), \theta)\big)$ as the second term must be positive. The cross partial derivative of $\log\big(\alpha(\tau(\theta), \theta)\big)$ is linked to the elasticity of demand with respect to transmission time. Using the general formula

$$\varepsilon[f(x)] = \frac{d \log f(x)}{d \log x}$$

to determine the elasticity of demand w.r.t transmission times using the general formula and equation (6) we can find

$$\varepsilon(\tau, \theta) \equiv -\frac{d \log\big(\alpha(\tau, \theta)\omega(p^*)\big)}{d \log(\tau)} \tag{19}$$

Note that $\log\big(\alpha(\tau(\theta), \theta)\big)$ appears in the numerator of this equation. Therefore the sign of the cross partial derivative and the sign of (19) will be the same. We can remove the strictly positive function $\omega(p^*)$ as it will not affect the sign of the elasticity[8].

$$-\frac{d \log\big(\alpha(\tau, \theta)\big)}{d \log(\tau)} = -\tau \frac{d \log\big(\alpha(\tau, \theta)\big)}{d(\tau)} \tag{20}$$

If we take the derivative of this final term with respect to θ then this will have the same sign as the cross partial derivative of $\log\big(\alpha(\tau(\theta), \theta)\big)$. More formally

$$sign\left[\frac{d^2 \log\big(\alpha(\tau(\theta), \theta)\big)}{d\tau d\theta}\right] = sign\left[\frac{d\varepsilon(\tau, \theta)}{d\theta}\right] \tag{21}$$

This shows that whether and how much content should be prioritized depends on how elastic demand is with respect to transmission times, and how that varies across different contents.

Economides & Hermalin (2012) show in their Proposition 3 that, if we assume $d\varepsilon(\tau, \theta)/d\theta$ is monotone, then higher θ being more elastic, $\varepsilon(\tau, \theta) > \varepsilon(\tau, \theta')$, implies that welfare maximizing distributions entail shorter transmission times $\tau(\theta') > \tau(\theta)$. This suggests an optimal non-neutral allocation. However, if

$$\frac{d\varepsilon(\tau, \theta)}{d\theta} = 0$$

then the welfare maximizing solution is the net neutral allocation. These results are intuitive if we remember that total content traded is a sufficient statistic for welfare.

A key conclusion to remember here is that the result hinges on the elasticity of different content with respect to delivery time. This means that, given $\theta > \theta'$, if θ content is more elastic than θ' content and thus faces a larger change in demand when transmission times change. Then under a neutral regime they would have the same transmission times, but

---

[8]Note an error in Economides & Hermalin (2012), which equates the right hand side of (19) with the left hand side of (20) which is only true in sign.

shifting bandwidth from θ' content to θ content, thus changing the transmission times, would increase demand for θ more than it decreases demand for θ' thus increasing total content traded and thus increasing welfare. Thus net neutrality is not welfare optimal. In contrast no such welfare increase is possible in the latter case, thus net neutrality is welfare optimal.

It is important to note that earlier assumptions require that higher θ content is more sensitive to transmission times than lower θ content by definition. This can be expressed as

$$\frac{d^2\alpha(\tau(\theta),\theta)}{d\theta d\tau} < 0.$$

This does not imply anything about the sign of equation (21). This is a crucial distinction because it is possible to have solutions where prioritizing lower θ content over higher θ content is the welfare maximising solution. This possibility goes against intuition, but is possible due to households being able to reoptimise their consumption decisions[9].

A special case of this result can be shown if it is assumed that the preference function can be decomposed into two different functions, that is if the preference function is multiplicatively separable

$$\alpha(t,\theta) = \gamma(\tau)v(\theta). \tag{22}$$

With some additional assumptions on those functions[10], this decomposition directly implies

$$\frac{d\varepsilon(\tau,\theta)}{d\theta} = 0.$$

Thus, due to the result we found earlier, if preference function is separable and $g(t)$ is convex, then a net neutral regime is strictly welfare superior to any non-neutral regime that excludes a non-zero amount of content. It is also strictly welfare superior to any regime where different transmission times for different content providers arise. A net neutral regime is now weakly welfare superior to any non-neutral regime (Economides & Hermalin, 2012).

2.2.4 Internet service provider's pricing decisions and welfare effects

The previous section addressed the efficient allocations possible with a centralised solution, but did not address whether the ISP would choose to price in this manner when unconstrained, this will be addressed in this section.

[9] See Economides and Hermalin (2012) page 612 for an explanation and a more comprehensive example

[10] $\gamma(\tau) > 0, v(\theta) > 0, \gamma'(\tau) < 0, v'^{(\theta)} > 0, g(t) = \frac{t}{\gamma(\tau)}, g(t) > 0, g'(t) > 0, g''(t) > 0$

This is a two sided pricing model, which means that the ISP is able to both charge households for their access to the internet, while also charging CPs an access fee to transfer their content. In a neutral regime, the price charged to CPs by the ISP is constrained to zero and thus the only strategic decision left to the ISP is the price of the connection fee for households, denoted η. In a non-neutral regime, the ISP is free to select the profit maximising combination of both fees. In earlier results, it was shown that excluding a range of content providers via blocking was welfare harming. This leads to our next result for the ISP pricing decisions. Suppose ISP charges content providers an access fee, with a single tier of service, denoting this access fee s. If $s > 0$ and the equilibrium results in any content providers not providing content due to the fee, then the equilibrium is welfare inferior to a regime where $s = 0$. This is because the latter regime increases total content traded, which is a sufficient statistic for welfare. This result is not obvious, as although there is no marginal cost of supply to the ISP, there is a marginal external cost via congestion and higher transmission times. The result hinges on the ability of households to internalize congestion into their optimization decision, and thus reducing their opportunity set can never be welfare increasing.

It was earlier shown that blocking is welfare harming, and it was shown that pricing with a single positive price is also welfare harming. The next step is to investigate the welfare effects of prioritization in the context of both feasible optimal pricing and tiering decisions, and furthermore, whether these optimal prices will be selected by the ISP in a non-neutral regime.

A reasonable assumption is that, as the individual transmission time for any given content goes to infinity, the preference function, $\alpha(t_i, \theta)$ approaches zero. This is rational in practical terms, as extreme transmission times can completely degrade the value of the content. Formally this assumption is shown as

$$\lim_{\tau \to \infty} \alpha(\tau, \theta) = 0 \; for \; all \; \theta \; \forall \; [\underline{\theta}, \overline{\theta}) \tag{23}$$

Suppose there are two services, where a prime denotes the higher tier of service: transmission times $\tau' < \tau$, and corresponding prices $s' > s$. If the lower content type θ' maximises profit by selecting higher tier prioritization, then

$$(p^* + q - c)\omega(p^*)\alpha(\tau', \theta') - s' \geq (p^* + q - c)\omega(p^*)\alpha(\tau, \theta') - s, \tag{24}$$

which is the same as

$$\pi(CP)\alpha(\tau',\theta') - s' \geq \pi(CP)\alpha(\tau,\theta') - s, \tag{25}$$

From equation (4), we know that $\alpha(\tau',\theta') > \alpha(\tau,\theta')$. It follows that

$$\pi(CP)[\alpha(\tau',\theta') - \alpha(\tau,\theta')] \geq s' - s.$$

Substituting equation (5) into the parenthesis, and taking into account the strict inequality in equation (4), we can rearrange the result to find that equation (25) implies the following:

$$\pi(CP)\alpha(\tau',\theta) - s' > \pi(CP)\alpha(\tau,\theta) - s. \tag{26}$$

This result shows that, if any lower θ content chooses higher tiered service, then all content providers with higher θ strictly prefer this service also. Thus if any content providers decide to exit the market due to $s > 0$, then it will be the lowest θ content providers who exit first. This result is intuitive in that, if a content provider who is less sensitive to transmission time prefers a lower transmission time, coupled with a higher access fee price, then content which is more sensitive to transmission times must also prefer the lower transmission time and higher access fee. Furthermore, the higher θ content must have a greater utility gain from the higher tier service relative to the lower service. This result also conveniently rules out discontinuous or mixed strategies for CPs. This, in combination with the relationship between demand elasticity and the cross partial derivative of transmission and content providers found earlier, allows us to make statements about the welfare effects of prioritization.

Economides and Hermalin (2012) show in their proposition 5 that, if

$$\frac{d\varepsilon(\tau,\theta)}{d\theta} \leq 0, \tag{27a}$$

then no non-neutral regime with price discrimination provides higher welfare than the neutral regime, i.e. net neutrality is welfare superior. However, if

$$\frac{d\varepsilon(\tau,\theta)}{d\theta} > 0, \tag{27b}$$

then there is a welfare maximizing non-neutral regime which is welfare superior to net neutrality. This result does not state that the market will reach a welfare superior result if (27b) is true; it only provides that such a solution exists. Typically ISP profit maximization and welfare maximization do not perfectly align. It is difficult to say whether pricing decisions of ISPs will generally harm or help welfare in the latter case without further analysis. It also needs to be examined whether ISPs will choose a positive price if not constrained, as otherwise the regime choice is somewhat irrelevant. The key result here is that always using a neutrality regime cannot be welfare improving relative to optimal policy decisions.

In determining the ISP's pricing decisions, the ISP's profit function must be derived. The ISP's pricing decisions for both CPs, via s, and for household connection fees, via η, need to be considered, where η is the connection fee charged to households for connection to the internet:

$$\eta = \int_{\underline{\theta}}^{\overline{\theta}} \sigma\alpha(\tau(\theta), \theta)dF(\theta) \tag{28a}$$

The ISP will capture the entire consumer surplus given homogenous households[11]. This result occurs regardless of which regime is chosen. This can also be shown as a share of total equilibrium welfare,

$$\eta = \frac{\sigma}{(\pi + \sigma)}W. \tag{28}$$

Here the ISP partially internalizes welfare into its profit function, which leads to the next result. If ISP pricing scheme is not welfare maximizing, then enforcing a neutral regime will lead to an increase in η as W increases. This does not affect households' welfare in this model because the ISP captures their entire surplus regardless of the price they face in equilibrium[12].

We now turn to the maximization of the ISP's profit. Given the bandwidth constraint in (16), ISP profit is a function of both the connection fee for households, and the connection fee for CPs. If we allow for continuous price discrimination across content providers and assume that $\tau(\theta)$ is a non increasing function, then it can be shown that this can lead to 'too much' price discrimination from a welfare perspective (Economides & Hermalin, 2012) [13].

However these results do not reflect realistic circumstances where currently proposals involve a finite number of tiers. Suppose instead that the ISP is limited to offering two tiers of prioritization. I will use h and l subscripts to denote high and low tiers respectively. This implies that $\tau_h < \tau_l$, with respective prices s_h and s_l. Content providers have the choice

[11] Even with heterogeneous households, the ISP can still perfectly price discriminate. Economides & Hermalin (2012) show that the results here do no hinge on homogenous households.
[12] Economides & Hermalin note this as a possible factor in political economics surrounding this issue, but this is not a focus of this thesis.
[13] Note that this does not use the multiplicatively separable assumption.

between the higher priority tier, the lower priority tier, and not purchasing either. Formally, their profits when selecting each of the tiers are given by:

$$\Pi_{cp}(0) = 0,$$
$$\Pi_{cp}(\mathrm{l}) = \pi\alpha(\tau_l, \theta) - s_l,$$
$$\Pi_{cp}(\mathrm{h}) = \pi\alpha(\tau_h, \theta) - s_h.$$

Given that $\theta > \theta'$, let the subscripts l, h and 0 be the pair of t_x and s_x, either high, low or zero. Assume r denote a higher service than r'. If the θ type prefers a lower service to a higher one, that is $h \prec l$, $h \prec 0$ or $l \prec 0$, then the θ' type content providers must also follow these preferences. Equivalently, if the θ' type content producers prefer a higher service type to a lower one, $h \succ l$, $h \succ 0$ or $l \succ 0$, then the θ type content providers must also hold the same preferences. Thus, the only time we have discrimination is when the θ type content providers select a higher tier of prioritization than the θ' type content providers.

Given the continuum of content providers there must exist two cut-off points that separate the content providers into ranges that select respective services. We can denote these cut-off values as θ_l and θ_h, where $\underline{\theta} < \theta_l < \theta_h < \bar{\theta}$. All $\theta > \theta_h$ will choose the high priority service, all $\theta < \theta_l$ will choose no service, or in other words will not enter the market. While $\theta_l < \theta < \theta_h$ will choose the low priority service. Content providers on cut-off values are indifferent.

The ISP will price s_l so that the cutoff θ_l content provider will have its profits fully extracted. If s_l didn't fully extract this, then the ISP could increase profits by increasing s_l without affecting demand. Also, if s_l is higher than the cut-off content provider's surplus, then the θ_l content provider will not enter the market, and thus reducing s_l will increase demand more than it harms profit per content provider. Therefore, allowing the cut-off content provider's surplus to be fully extracted, we arrive at

$$s_l = \alpha(t_l, \theta_l)\pi. \tag{29}$$

Solving for s_h is more complicated as the cutoff value is indifferent between earning the same positive profit from selecting s_h or s_l. In this sense, the ISP is unable to fully capture the profits, and this mimics the traditional adverse selection issue.

$$\alpha(t_h, \theta_h)\pi - s_h = \alpha(t_l, \theta_h)\pi - s_l$$

Rearranging and using equation (29) to substitute s_l, this leads to

$$s_h = \alpha(t_h, \theta_h)\pi - \alpha(t_l, \theta_h)\pi + s_l$$

$$s_h = \pi[\alpha(t_h, \theta_h) - \alpha(t_l, \theta_h) + \alpha(t_l, \theta_l)]$$

The profit function for ISPs in this setup can be written as

$$Profit(ISP) = \big(1 - F(\theta_l)\big)s_l + \big(1 - F(\theta_h)\big)(s_h - s_l) + \eta \tag{30}$$

In order to further define this profit function, the multiplicatively separable preference function assumed earlier in (22) is required. Furthermore, for simplicity it is useful to define the integral of the decomposed preference function for content as

$$I(\theta_1, \theta_2) = \int_{\theta_1}^{\theta_2} v(\theta)dF(\theta), \tag{31}$$

while also making a notational simplification in the form of

$$G(z) = g^{-1}(z). \tag{32}$$

The appendix provides a comprehensive transformation from (30) to (33), which uses equations (22), (31), (32) and (28a) to find

$$\begin{aligned} Profit(ISP) = {} & \big(1 - F(\theta_l)\big)\pi v(\theta_l) y\left(G\left[\frac{\omega(p^*)I(\theta_l, \theta_h)}{B_l}\right]\right) \\ & + \big(1 - F(\theta_h)\big)\pi v(\theta_h) y\left(G\left[\frac{\omega(p^*)I(\theta_h, \bar{\theta})}{B_h}\right]\right) \\ & - \pi v(\theta_l) y\left(G\left[\frac{\omega(p^*)I(\theta_l, \theta_h)}{B_l}\right]\right)) \\ & + \left[\frac{B_l G(\frac{\omega(p^*)I(\theta_l, \theta_h)}{B_l})}{\omega(p^*)} + \frac{B_h G(\frac{\omega(p^*)I(\theta_h, \bar{\theta})}{B_h})}{\omega(p^*)}\right] \end{aligned} \tag{33}$$

If a net neutrality regime were in place, and the access fee charged was the price required to not exclude any content, this would be the price that extracts the entirety of the lowest content provider's surplus. Formally the optimal pricing scheme given these restrictions is $s = \pi\alpha(t^*, \underline{\theta})$. Define $\hat{\theta}$ that solves $I(\underline{\theta}, \hat{\theta}) = I(\hat{\theta}, \bar{\theta})$ or equivalently $\int_{\underline{\theta}}^{\hat{\theta}} v(\theta)dF(\theta) = \int_{\hat{\theta}}^{\bar{\theta}} v(\theta)dF(\theta)$. Given no exclusion and a neutral regime, it is equivalent to the following tiering system, $B_l = B_h = B/2, s_l = s_h = v(\underline{\theta})y(t^*),\ \theta_l = \underline{\theta}, \theta_h = \hat{\theta}$.

Given the above adjustment function being separable as described in equation (22), ISPs will strictly prefer non-neutral regimes and a non-neutral solution if unconstrained (proof can be found in Economides & Hermalin (2012)). This is intuitive, as with only one ISP in this model, allowing non-neutrality expands its strategic set and thus cannot harm its profits. This result wouldn't necessarily apply in models with more than one ISP in direct competition with each other. But in this setting a non-neutral regime allows the ISP to price discriminate and extract additional surplus from the content providers, in addition to the surplus they fully extract from the households.

The next result relies on a number of assumptions: firstly, that $\alpha(t, \theta)$ is multiplicatively separable. Secondly, that the function $g(t) = t/\gamma(t)$ is convex, and finally, that the ISP uses imperfect (or limited) price discrimination against content providers. With these assumptions in place, the paid prioritization (or non net neutral) regime that maximises the ISP's profits does not maximise welfare. This result is intuitive, as earlier it was shown that excluding content providers is welfare harming. In this case non-neutral pricing involves strictly positive prices for each tier, which can exclude content providers from the market when it drives their profits below zero, which occurs when $\theta_l > \underline{\theta}$. This pricing allocation must necessarily decrease the total content exchanged and thus decrease total welfare[14].

However, if we allow for perfect price discrimination by the ISP, then the ISP will select the welfare maximizing tiering allocation. This is intuitive as when the ISP price discriminates perfectly to both the household and the contents providers, the ISP extracts the entire surplus of both, and thus, as the ISP's total profit is the total welfare of the model, maximizing welfare maximizes the ISP's profit. In perfect price discrimination, no content providers that would otherwise provide content are excluded and thus welfare is not harmed in the same manner as the imperfect case.

2.2.5 Dynamic effects on welfare

The dynamic effects of the different regimes can be shown in this model via an endogenous B. Up until this point, the results have all assumed an exogenously given B that does not depend on any of the respective players' surpluses or the total welfare of the network. This analysis is essentially a static view of the economy, as in the short term bandwidth is fixed.

[14] Note that this is analogous to the argument proposed to show that blocking is welfare harming.

However, in a dynamic setting bandwidth is a function of investment and can be increased or decreased over time. This section will analyse the investment decisions of the ISP with respect to different regimes. We assume a marginal cost of bandwidth of $k > 0$. For simplicity we assume $k' = 0$, i.e. k is constant. Moreover, we let $\alpha(\tau, \theta) = \theta/\tau$ and F is uniform on $[0,1]$. This special case satisfies condition (22). With continuous discrimination instead of discrete discrimination across content providers, the ISP profit function can be given by:

$$Profit(ISP) = \eta + \int_{\underline{\theta}}^{\overline{\theta}} \left[\pi\alpha(\tau(\theta), \theta) - \pi \frac{1 - F(\theta)}{f(\theta)} \frac{\delta\alpha(\tau(\theta), \theta)}{\delta\theta}\right] dF(\theta) d\theta \tag{34}$$

Note that this is the continuous equivalent to (33) with continuous pricing options. Modifying this equation with the new assumptions and with the bandwidth investment decision now embedded into the equation we can show that the problem can be stated as

$$\max_{\tau(\theta)} \int_{\underline{\theta}}^{\overline{\theta}} \left(\left(\sigma + 2\pi - \frac{k\omega(p^*)}{\tau(\theta)}\right)\theta - \pi\right) \frac{1}{\tau(\theta)} d\theta \tag{35}$$

The solution to this equation is

$$\tau(\theta) = \infty, if\ \theta \leq \frac{\pi}{\sigma + 2\pi}$$

$$\tau(\theta) = \frac{2k\theta\omega(p^*)}{(2\pi + \sigma)\theta - \pi}, if\ \theta > \frac{\pi}{\sigma + 2\pi}$$

From this solution we can define the level of bandwidth the unconstrained ISP would select. Starting with equation (16) and substituting the range of θ into it we find

$$B_{non\ neutral} = \omega(p^*) \int_{\underline{\theta}}^{\overline{\theta}} \frac{\alpha(\tau(\theta), \theta)}{\tau(\theta)} dF(\theta) \tag{36}$$

$$= \int_{\frac{\pi}{\sigma+2\pi}}^{1} \frac{\alpha(\tau(\theta), \theta)[(2\pi + \sigma)\theta - \pi]}{2k\theta} dF(\theta)$$

Then substituting the explicit form of the preference it can be shown that

$$\alpha(\tau(\theta), \theta) = \frac{\theta}{\tau} = \frac{((2\pi + \sigma)\theta - \pi)\theta}{2k\theta\omega(p^*)}$$

$$B_{non\ neutral} = \int_{\frac{\pi}{\sigma+2\pi}}^{1} \frac{[(2\pi + \sigma)\theta - \pi]^2}{4k^2\theta\omega(p^*)} dF(\theta) = \frac{\sigma^2 - \pi^2 + 2\pi^2 \log\frac{2\pi + \sigma}{\pi}}{8k^2\omega(p^*)} \tag{37}$$

Through equivalent calculations for the neutral regime it can be shown that

$$B_{neutral} = \frac{\sigma^2}{8k^2\omega(p^*)} \tag{38}$$

as the neutral regime is essentially setting $\pi = 0$. In order to determine which regime leads to higher investment we need to determine the sign of

$$-\pi^2 + 2\pi^2 \log \frac{2\pi + \sigma}{\pi} = -\pi^2 (1 - 2 \log \left(2 + \frac{\sigma}{\pi} \right))$$

where a negative sign indicates that a neutral regime leads to higher bandwidth and a positive sign indicating that a non-neutral regime leads to higher bandwidth, as π and σ are strictly positive, if the interior of the bracket is negative then the equation is positive. As

$$2 \log 2 > 1$$

then the equation is positive for any values of π and σ, and therefore a non-neutral regime leads to higher total bandwidth in equilibrium. This result is expected, as the ability to discriminate to some extent internalizes the total welfare, as we found in previous results. Internalizing welfare means that the ISP now has a larger incentive to invest, as the externalities that CPs and households experience from this additional investment now directly result in greater profits to the ISP. Now we turn towards the welfare effects taking into account an endogenous bandwidth supply, using equation (11) and (16). Accounting for the marginal cost of supply, it can be shown that

$$W = \int_{\underline{\theta}}^{\overline{\theta}} (\pi + \sigma - \frac{k\omega(p^*)}{\tau(\theta)}) \alpha(\tau(\theta), \theta) dF(\theta) \tag{39}$$

which yields different solutions for the neutral and non-neutral regimes,

$$W_{neutral} = \frac{2\pi\sigma + \sigma^2}{8k^2\omega(p^*)} \tag{40}$$

$$W_{non\ neutral} = \frac{(\pi + \sigma)(4\pi^2 + 3\pi\sigma + \sigma^2) - \pi^2(4\pi + 2\sigma) \log\left(\frac{2\pi + \sigma}{\pi}\right)}{8k^2\omega(p^*)(2\pi + \sigma)} \tag{41}$$

$$W_{neutral} \lesseqgtr W_{non\ neutral}$$

This is due to the relative values of welfare in each regime being dependent on the values of π and σ. Once ISP investment decisions are introduced, net neutrality regimes may still be welfare optimal, but no longer must be. Letting $\sigma = \pi h$, we have that $W_{neutral} < W_{non\ neutral}$ if and only if

$$4 + 3h - 2(2 + h) \log(2 + h) \geq 0$$

where h satisfies this equation in equality if

$$h \approx 1.314$$

Economides & Hermalin (2012) state in their proposition 9 that given all assumptions made in this result, the ISP will always invest more in bandwidth in the non-neutral regime, and this will lead to a higher welfare if $h < 1.314$. However, if $h > 1.314$ then the neutral regime is still welfare superior, even with lower total bandwidth supply. This result is striking, as it shows the difference in optimal policy between static and dynamic settings. It also shows that allowing price discrimination and tiering always leads to higher bandwidth supply, which is akin to higher investment in infrastructure. This is due to the fact that, in this model, the ISP can extract some of the surplus of the CP, thus leading it to internalize the increase in content traded from a higher supply of bandwidth.

3 Discussion

In this section, I will begin with a discussion of the implications of the results, as well as limitations, future areas of interest and comparisons with other areas of the literature on net neutrality. I will continue on to contrast and make connections with other regulatory decisions and expand on the answers to the research questions that were addressed with the model.

3.1 Implications and summary of results

3.1.1 Results

Total content traded is a sufficient statistic for welfare

This result means that using total content traded as a ranking measure perfectly preserves the welfare ranking and magnitude between different regimes. This greatly simplifies calculations and directly implies many of the following results. It is also somewhat intuitive, as the surplus from trade that exists between the CPs and households can never be negative in a marginal sense. Any content that is traded must at worst have a net surplus of zero, because any price that leads to the household having a negative surplus, i.e. the value of the good is less than the price, would not result in exchange. Equivalently, any price of content that is below the marginal cost of providing the content will not be produced by CPs. Therefore, only cases where the surplus of either party is at worst zero must occur in exchange. This implies that higher exchange of content from consumers to content providers must increase total welfare. The preference function does offer an interesting complication in that there is a social marginal cost of congestion, but this is internalised to some degree by households and as a result, does not alter the above intuition.

Blocking is welfare harming

The above result implies that blocking has a negative effect on welfare. This result can be extended to throttling. This has policy implications, because ensuring that blocking and throttling behaviour are eliminated entirely improves overall welfare, regardless of the frequency in which these acts occur. Blocking and throttling being welfare harming should not be an unexpected consequence, as both concepts entail a deliberate degradation of the quality of service to the household, either in the form of reduced range of content to select from in terms of blocking, or increased transmission times lowering the value of the content artificially in the case of throttling. In contrast to efficient rent extraction which infer a direct transfer from one party to another with no loss to the system, these practices degrade the value of certain content within the network with no trade-off of increased value elsewhere.

The welfare effect of prioritization depends on $d\varepsilon(\tau, \theta)/d\theta$

The welfare effect of prioritization depends on whether the elasticity with respect to transmission time varies across content providers. If it does, then the optimal allocation can be non-neutral, and thus removing net neutrality can be welfare improving. However, if the partial derivative is equal to zero, then the net neutral regime is welfare optimal and thus removing it can only be welfare harming. Following on from this, if the preference function is multiplicatively separable and is concave in transmission time, then net neutrality is strictly welfare superior to any non-neutral regime which excludes any amount of content, or imposes different transmission times in equilibrium. If demand for content is equally sensitive to transmission time across different content providers, then keeping all content transmission times equal is the most effective way to maximise demand. This is because it allows consumers to spread their consumption most effectively across the range of content providers, by allowing them to take a more efficient bundle of content, without any distortions to the first best allocation due to varied transmission times. This is an optimal allocation for households as a result of the diminishing marginal utility of any given content it consumes. Given the option, households strictly prefer a varied content portfolio to consume, rather than one containing multiple units of the same type of content.

The ISP strictly prefers non-neutral regimes

Provided that the preference function is multiplicatively separable, the ISP will strictly prefer non-neutral regimes and will implement a positive price for content providers to enter the network. This is a reasonable result as with a single ISP the ability to set positive prices CPs yields an additional revenue stream with no. As a monopolist, the ISP must always weakly prefer non-neutral regimes as they can still choose to charge a price of zero to CPs if that maximises profit. In other words allowing the ISP more strategic choices can never harm its profit. With the above assumptions the ISP now strictly prefers non-neutral regimes and would choose to implement a price of greater than zero for CPs. It is interesting to note that any price that does not force any content providers to exit the market is essentially just a transfer from the CPs to the ISP and has no total welfare effect.

The welfare optimal regime depends on the degree of price discrimination with fixed bandwidth supply

With imperfect price discrimination, assuming a multiplicatively separable preference function, the allocation selected by the ISP is not welfare optimal. However, if perfect price discrimination is used, then the ISP selects welfare optimal prices and tiers, and a non-neutral regime is welfare optimal. In the former case, the ISP only extracts part of the surplus from the CPs, so it only partially internalises the welfare losses from setting prices in a way that lowers total content exchanged. The ISP then faces a trade-off between maximising the amount of surplus that can be extracted from CPs, and the number of content providers that can be induced to stay in the market. The profit maximising result will entail some exit from the market and thus will be welfare harming, therefore a neutral regime would be preferable from a welfare perspective. In contrast, with perfect price discrimination the ISP completely expropriates the surplus of the content providers. Therefore, given the ISP already claims the entire consumer surplus, the ISP's profit is the same as total welfare, and incentives align perfectly. Therefore, the non-neutral regime is welfare optimal with perfect price discrimination.

Net neutrality negatively affects investment by the ISP

It is clear that a neutral regime negatively affects profits of the ISP. The reduction in profits directly leads to a reduction in investment for ISPs. This reduces the total bandwidth of the network. The reduction in profits occurs in all future periods, so it dramatically reduces the net present value of the ISPs. Furthermore, not only does it affect the value of the industry, which is directly tied to its ability to raise capital, but it also reduces the value of the future investment. As the ISP is unable to extract any of the additional profits the CPs receive from a higher bandwidth supply, the ISP can only extract the additional surplus enjoyed by the HH. Without being able to extract some rent from CPs, the ISP does not internalise enough of the positive externalities of a more powerful network, and thus selects a socially insufficient level of investment. Although in this model the ISP invests in a higher bandwidth capacity, this can be generalised to maintenance, existing infrastructure upgrades, and building next generation networks. This result is particularly important due to the positive externality investment in infrastructure has on all end users of the internet in the real world, and this will be addressed later.

The effect on welfare in a dynamic setting from net neutrality is ambiguous

Again assuming perfect price discrimination and a multiplicatively separable preference function, the welfare superior regime depends crucially on the values of π and σ, the profit share of the CPs, and the consumer surplus from that sale respectively. In order for there to be welfare indifference between net neutrality and a non-neutral policy, it must be the case that $\sigma \approx \pi 1.314$. So if the consumer surplus per unit of content is larger than this indifference point, or $\sigma > \pi 1.314$ then allowing paid prioritization is welfare optimal. However, if the consumer surplus is below this indifference point, or $\sigma < \pi 1.314$, then net neutrality would be the welfare optimal solution. Therefore in order for a non-neutral regime to be weakly welfare superior to the neutral regime, the following relationship must hold:

$$1.314(p^* + q - c)\omega(p^*) \leq \int_{p^*}^{\infty} \omega(p)dp$$

This equation allows us to discuss market conditions that are more likely to lead to non-neutral regimes being optimal. The profit share is defined by the margin the CP receives on each unit of content traded $p^* + q - c$, where c is the marginal cost of producing content, q is the advertising rate and p^* is the optimal price to households to purchase content. Lower profit shares are more likely to lead to non-neutral regimes being optimal, which is intuitive as lower profit shares imply a certain degree of competition, or sufficiently sensitive demand. As the ISP fully extracts the CPs' profit in this model, this matches the results many studies find, that strong competition between ISPs can minimize the requirement for, or even replace net neutrality laws (Wallsten & Hausladen, 2009; Wang et al., 2014). Lowering the optimal price p^* increases the right hand side of this equation, the consumer surplus, by lowering the lower bound of the integration. Intuitively, it is increasing the consumer surplus for all consumers who already purchase the content by a linear amount. It also increases the number of consumers that purchase the content as $\omega(p)$ is decreasing in p^*, which is expected of a downward sloping demand function. The effect of decreasing p^* on the left hand side of the equation is more ambiguous as the number of consumers purchasing the content increases, yet the margin on each piece of content sold decreases. When the price is at the optimal level, p^* an increase or decrease in price will reduce the total profit of the CPs (and by extension the ISP) by definition. It can also be inferred that higher advertising revenues decrease the likelihood that a non-neutral regime is welfare optimal, and the same conclusion can be reached for lower marginal costs. This is an especially important result as it implies that there can be different policy solutions for different countries, depending on the amount of market power or competitiveness in the content provider market.

3.1.2 Realism of the model's assumptions

ISP monopoly

Is it reasonable to model the ISP as a monopolist, despite all of the major economic areas we have focused on (the US, Europe and Norway) having some degree of competition? In some regards ISPs intrinsically hold a monopoly over a certain market segment, as they are the only connection to households subscribed to their servers (Krämer et al., 2013). However, even some degree of competition can partially mitigate this market power and with HH being able to switch ISPs easily, this drastically reduces the market power of ISPs.

If modelling with ISP competition embedded into the model is considered, it could potentially have some effects on the results and mechanisms. As with some degree of competition between ISPs, the consumer surplus may no longer be entirely expropriated, because competition would mitigate the ability to perfectly price discriminate.

It is also no longer clear that ISPs will prefer a larger array of pricing choices, as restraining the decisions of all ISPs collectively could lead to higher profits for ISPs individually. Net neutrality regulations that prevent all ISPs from setting positive prices for CPs could improve the ISPs' profits in some cases.. This is because charging the CPs can hurt the total content exchanged and reduce the surplus that HH receive, and ISPs extract. Thus, ISPs might prefer that all ISPs are constrained by net neutrality. This is despite charging CPs being a dominant strategy, in the same way that removing the ability to defect in the traditional prisoners dilemma game can improve all players' outcomes[15]. In the case of multiple ISPs, strategic decisions and effects can lead to dynamic inefficiencies (Bourreau, Kourandi, & Valletti, 2015). These can likely be avoided in real life by coordination, both within the industry and by the regulator.

Multiplicatively separable preference function

A multiplicatively separable preference function was a prerequisite for determining the

[15] The traditional prisoners dilemma game involves 2 players, who can choose to cooperate or defect. Both players have the dominant strategy to defect, but would both be strictly better off if both were constrained to cooperate only. In that sense the equilibrium of the game is not welfare maximizing if constraint is possible.

decisions of the ISP's pricing strategies in a static setting, as well as determining the welfare effects of prioritization in both the static and dynamic settings. As such, it is appropriate to address whether this is a reasonable assumption to make. This assumption is known as a regularity assumption. It imposes some restrictions while making comparison and calculations tractable, although it does reduce the game space in some sense, as it excludes possible preference functions. In practical terms, it is a very reasonable assumption that does not influence the applicability and validity of the results.

Constant marginal investment costs

In terms of simplicity and tractability of the model, applying constant marginal costs for investment is certainly justified. In the long term, as no costs are truly fixed or sunk in larger timeframes, constant marginal costs seems to be a reasonable approximation of real life generally. What it does fail to capture in this model is the minimum required investment in order to build a next generation network. A better representation of real life conditions would have a minimum level of required investment in order to build the next generation network. Depending on calibration and the thresholds assigned, this could have a varied effect. This critique seems to be supported by the fact that Verizon and other ISPs have opted to indefinitely delay or halt fibre optic infrastructure rollouts indefinitely, rather than scaling back the degree of investment incrementally.

Alternatively, when comparing the selection of constant marginal costs with potentially increasing or decreasing marginal costs, the model selection is well justified. Choosing to use non-constant marginal costs implies allowing for economies or diseconomies of scale, or escalating or deescalating input costs, and there is no reason to incorporate these into the marginal cost curve. This is because real world equivalent investments often entail deployment to more geographic areas rather than an additional upgrade on top of prior investment, in this sense keeping marginal costs of investment and, implicitly, the marginal product of investment constant, seems very reasonable.

Is total welfare or consumer surplus a better measurement of societal gain?

Many competition watchdogs use consumer surplus as a measure of welfare when considering mergers or other activities that may decrease competition (Pittman, 2007; Tirole, 1988). This is motivated by the implication that any merger that is attempted must be privately profitable, thus when agencies know the companies are increasing profit, their primary concern becomes the consumer (Whinston, 2007). This raises the question of whether consumer surplus should also be used in net neutrality debates to determine optimal policy. This is because consumer surplus and total welfare do not necessarily correlate positively or strongly, and the welfare maximising outcome does not necessarily maximise the consumer surplus[16]. It can be argued that the ideal regulatory regime should be determined by consumer surplus rather than total welfare. This is because the profit maximising outputs of corporations do not benefit households. An opposing argument is that total welfare can be considered a more accurate view of the benefits to society. This is because total welfare essentially takes into account all of the gains from trade, rather than those only occurring on the consumer end of the transaction. Increasing a corporation's profit whilst leaving consumers unaffected is valuable to society, especially when you consider that the shareholders of companies are usually the consumers, either through private holdings or public stakes, which are funded by their taxes. In Economides and Hermalin (2012), the consumer surplus is always zero, which is a product of the pricing schemes allowed and will be discussed below.

Perfect v imperfect price discrimination

The result of the static welfare optimisation decision between tiering and no tiering depends crucially on what degree of price discrimination is allowed within the model. Perfect discrimination allows the ISP to extract the entire market rent from the CPs. Which means the ISP obtains all of the welfare gains for the economy in the form of profits, as the ISP already extracts the entire consumer surplus. Because of this, the ISP's wealth maximisation and public welfare maximisation perfectly align. However this assumption is unrealistic for a number of reasons. Firstly, perfect price discrimination means to make all CPs indifferent between entry and no entry, thus charging a unique price to each CP based on their exact profit function. This requires the rather unreasonable real world assumption of perfect information. Secondly, it also relies on no uncertainty existing in the model and a very simple cost curve for content providers. In reality, the ISP working as a monopoly would be able to extract some of the surplus from CPs, but not the entire amount. It would thus be more realistic to model this with a finite number of tiers as a restriction constraining the ISP. This restriction directly implies imperfect price discrimination. Other models within the literature have yielded similar outcomes, finding that the results are dependent on the amount of

[16] In Economides & Hermalin (2012) the HH always had their surplus fully extracted in all equilibriums and so were indifferent, which is an unrealistic but useful simplification.

discrimination allowed. Some have used perfect discrimination and found non-neutral regimes to be welfare maximising (Coucheney, Maillé, & Tuffin, 2012; Wang et al., 2014). Baranes (2014) used a two tier system and found an ambiguous results. This is encouraging, as it provides some evidence that an imperfect discrimination extension of Economides and Hermalin's (2012) dynamic setting might also lead to an ambiguous result.

This is also an issue with the household consumption, as allowing perfect price discrimination against households (which is assumed in all parts of this model) coupled with the ISP monopoly means that consumer surplus is always zero. It also removes the potential trade off between lowering access fees for consumers and raising fees for CPs in order to improve ISP profits, as the ISP always captures the entire CP, in any case. Allowing HHs to not only retain surplus, but also allowing a non trivial decision about choosing to consume any internet access at all, seems like a reasonable possible extension or alternative viewpoint worth exploring. Sidak (2006) explores this direction, with non-perfect price discrimination for HHs, and as a result finds that not all households purchase the connection to the internet in equilibrium. He frames the issue as a trade off between innovation and investment within the content market, and investment in core infrastructure of the network. Sidak (2006) concludes in favour of paid prioritization because it leads to lower broadband access fees, and thus more consumers. There is a reasonable argument as to whether internet accessibility for households is limited by geographical installation and rollouts of networks, or whether a meaningful segment of the market is priced out.

3.1.3 How the results compare with other models

This model is an extension of an earlier paper written by Choi and Kim (2010), who found that paid prioritization decreases investment incentives for the ISP, directly contradicting the results of this model. They also find that paid prioritization weakens CP investment incentives, which, if we assume that investment incentives decreases with a decrease in profitability, is consistent with the results of Economides and Hermalin (2012). There are a large number of two sided pricing models that will be discussed here, some of which contrast the results of this thesis, while others support it.

Baranes (2014) focuses on modeling geographic spread of investment by having two segments of internet access, some with access to low speed only, and others with access to both low and high speed. He finds the welfare effects to be ambiguous, and under certain conditions he also finds that a non-neutral regime could increase investment and lead to welfare gains, both of which are consistent with the results of Economides and Hermalin (2012). Musacchio, Schwartz, and Walrand (2009) find an ambiguous welfare result when comparing the neutral and non-neutral regimes. They find that the likelihood in which the neutral regime is welfare superior is increasing the more competitive the ISP industry becomes. This last result is interesting, as it contradicts the theories that competition can be a substitute for net neutrality regulation (Kotrous, 2015). When considering two different types of content providers, small and large respectively, Courcoubetis, Sdrolias, and Weber (2014) find that paid prioritization increases CP profits when they derive most of their income direct fees, however, the result becomes ambiguous when CPs primary income is advertising revenue. This result indicates that a net neutral regime might actually harm CP profits under certain conditions. Positions on the effect of paid prioritization on CP investment have also been mixed, some finding investment increases, causing total welfare to also increase (Bourreau et al., 2015), whereas Gans (2014) finds that not only does it have a large negative effect on CP investment, but the effect on the investment of ISPs is negligible. There have been results which suggest that paid prioritization is unambiguously welfare superior, either due to erosion of ISP profits and thus investment lowering, or because the rent extraction from perfect price discrimination allows for the efficient allocation to be realized (Coucheney et al., 2012; Wang et al., 2014). However, others reach the opposite conclusion (Choi & Kim, 2010).

3.1.4 Future possible extensions

A growing population, endogenously increasing congestion over time

There is a wealth of empirical evidence suggesting that the levels of internet consumption will continue to grow steadily, with internet access becoming increasingly accessible in developing countries and many services in developed countries being shifted online (European Commission, 2014b; International Telecommunications Union, 2014; Statistics Norway, 2014). As both the number of users consuming internet and the average consumption per consumer is rising, it seems reasonable to build these two factors into the model in order to give a more representative picture of what the real world trends are.

Minimum investment requirement to increase the network capacity

This would be an interesting area of investigation, as it would more accurately reflect the investment decisions ISPs are faced with when determining different investment routes. Building next generation networks requires completion in order to bear any return, whereas upgrading existing networks can bear a marginal return, but is less efficient and will ultimately become insufficient. However, this direction of research would likely suffer from the need to calibrate the model in order to yield results. The size of the minimum investment relative to the profit function of the ISP would be crucial, as it would result in a binary investment decision, so the shift from no investment to investment and vice versa would likely be the determinant of optimal policy.

Multiple ISPs

As discussed above, there are very reasonable elements of the network structure that lead to ISPs having monopolistic power over some segment of the market. However, contrasting the general results with an extension involving competition between ISPs would introduce strategic effects that could alter results and lead to interesting conclusions. As discussed earlier, adding more competition is known to have a detrimental effect on ISP profitability and therefore investment (Baranes, 2014; Kotrous, 2015; Wallsten & Hausladen, 2009). This seems the most reasonable element to add into the existing model. A duopoly setting was addressed by Economides in a different model and was found to yield similar results (Economides & Tåg, 2012). Yet other models find that competition leads to the opposite conclusion (Coucheney et al., 2012; Wang et al., 2014). Interestingly, some also find that the introduction of competition makes the ISPs indifferent between regulatory regimes (Boussion, Maillé, & Tuffin, 2012).

Dynamic model with imperfect price discrimination

One of the largest criticisms of this model is that, while both perfect and imperfect price discrimination from the ISP to the CPs is considered in the static setting, only perfect price discrimination is considered with endogenous bandwidth supply. A very reasonable and direct extension of this model would involve exploring this case, although it is possible this would yield ambiguous results, owing to the ambiguous result the perfect price discrimination gave.

More emphasis on dynamic issues

The dynamic effects of net neutrality are in many respects the most crucial. Regulatory agents are tasked with maximising welfare of the population over an infinite horizon. In this sense the regulator has an obligation to future generations and must take future effects into consideration when making decisions in the present. Models should place emphasis on this long-term effect of net neutrality, as there is a large body of research on static outcomes already in place (Coucheney et al., 2012; Courcoubetis et al., 2014; Economides & Tåg, 2012; Wang et al., 2014), while existing models focusing on dynamic issues have given conflicting results (Baranes, 2014; Bourreau et al., 2015; Gans, 2014; Sidak, 2006).

3.2 Regulatory decisions and their effects

3.2.1 Prevalence of throttling and blocking

Both blocking and throttling have been shown to clearly decrease welfare. They are both also extremely anti-competitive practices that negate market participants' ability to compete on a fair and reasonable level. All content providers and regulators and a vast majority of ISPs state publicly that they are against throttling and blocking. Given the damaging result both for the industry and for welfare from these behaviours, prevention of these tactics should be a strategic factor for regulators to consider. Prevalence of these behaviours has been surprisingly common in both the US and the EU (BEREC, 2012; Ehrenfreund, 2014). In contrast, there have been no documented cases of throttling or blocking in Norway, This speaks to the success of the coregulatory approach discussed earlier. Norwegian oligopolies generally, and ISPs specifically, are extremely compliant and have active discourse and input when discussing these issues with NKOM and CCN. The prevalence of these anticompetitive behaviours should to some degree argue for more regulatory oversight to prevent it from continuing. For the Norwegian case, this implies that the coregulatory approach actually leads to requiring less regulatory oversight.

3.2.2 Investment and net neutrality regulation

Net neutrality has an unambiguously negative effect on ISP investment. In situations where net neutrality is welfare optimal, it is likely that this is a second best solution, with ISP investment being below socially efficient levels. Given the constant marginal costs and the network efficiency effects, it seem reasonable to assume that welfare is increasing over the relevant range of investment levels, ceterus paribus. Since investment is therefore socially sub optimal, it is useful to consider possible solutions in order to boost or prevent a reduction in ISP investment. One possible solution was offered by Economides (2008), who presents an argument in favour of net neutrality, while also finding a negative effect on ISP investment and suggests subsidisation as a possible solution to this issue. His position was motivated by the efficiency and welfare gains the infrastructure provides, due to network effects. If the ISP is unable to internalise enough of the positive externalities from CPs, then a possible solution is to subsidise the network investments. An alternative approach would be to reduce barriers to entry in the ISP market by lowering municipal regulation and requirements, which Kotrous (2015) offers as a viable alternative to net neutrality regulation. However, even if it is determined that net neutrality is optimal, the additional entry resulting from lower municipal requirements is still valuable if it leads to a relative boost in ISP investment. This issue is one that I feel is often overlooked or dismissed and is one of the key tensions within this debate.

3.2.3 Compulsory unbundling regulation

Effects in conjunction with net neutrality

Compulsory unbundling has an unambiguously negative effect on investment in next generation models (Wallsten & Hausladen, 2009). It also has a positive effect on the number of entrants and the amount of competition within the ISP industry, specifically within networks (Wallsten & Hausladen, 2009). Given this, it has been considered as a potential solution to net neutrality, although research suggests that it would be ineffective (Wallsten & Hausladen, 2009). The presence of compulsory unbundling could change the optimal policy for a given country, as compulsory unbundling has the same effect as strong net neutrality regulation, in terms of reducing ISP profit. Therefore, it also reduces investment incentives, both by lowering future profitability, and regulating that any company can rent parts of the next generation network from the incumbent. This regulation leads to a reduction not only of the profit from future investment, but also by completely removing the competitive advantage such a development would normally yield. Furthermore, it also introduces the possibility of renting bandwidth at a regulated low price from any competitor who chooses to build one. The strategic decision observed to occur most frequently is that all competitors opt to not invest in new networks (Wallsten & Hausladen, 2009).

Different regulation within each country

Compulsory unbundling has previously occurred in the US, but is not being considered as a regulatory measure for next generation models, largely owing to the relative failure to boost investment, as predicted. In contrast, compulsory unbundling was considered successful in both the UK and Norway (Crandall et al., 2013; NKOM, 2015; OECD, 2003; Wallsten & Hausladen, 2009). In both countries compulsory unbundling is applied to any monopolistic network to ensure sufficient competition (European Commission, 2010; NKOM, 2015). This has been stated to include the next generation internet access networks, or the fibre optics network referred to earlier (European Commission, 2010; NKOM, 2015). Research shows the similar effects this policy has on investment, competition, and potentially welfare, underlining the importance of considering these policies and effects in combination with a neutrality policy decision (Crandall et al., 2013; Nardotto et al., 2014; Wallsten & Hausladen, 2009). It follows that differing compulsory unbundling policies could lead to different net neutrality policy decisions between countries.

3.3 Potential differences in optimal policy between countries

Given the following three results: 1) the welfare maximising regime depends on the consumer surplus and profit share per content exchanged, 2) the investment in the next generation networks will be negatively affected by the neutral regime, 3) the degree of cooperation and related regulations vary between countries. It is reasonable to conclude that the ideal policy to implement may well vary between countries.

3.3.1 Europe

Since the optimal policy can vary between countries, it raises the question of whether the EU ruling to impose net neutrality will have a positive or negative effect on the welfare of consumers within those markets. Given the prevalence of blocking behaviour found in Europe (BEREC, 2012), it is reasonable to assume that the legislation will at least partially mitigate this phenomenon. The total welfare effect of the EC implementing net neutrality regulation will depend on both the sign and magnitude of the welfare shift caused by imposing neutrality in each individual country. More specifically, the total effect would depend on how many countries' optimal policies would involve non-neutral solutions, and how damaging the suboptimal non-neutral solutions would be for the others. This raises the familiar tension of Europe wide policies, as there is a diverse range of countries and markets collectively regulated by the EC. Thus, what is optimal for some countries will almost certainly introduce inefficiencies in others. However, the contrasting issue is that many companies compete and operate business across multiple countries and regions, and thus enforcing universal rules reduces the level of regulatory arbitrage possible. Furthermore, it enforces a clear and level playing field for both ISPs and CPs across Europe. Further research should be conducted to determine the relative welfare implications of suboptimal levels of regulation. More specifically, one should compare the cost of incorrectly implementing net neutrality in countries that do not require it, with the cost of failing to implement net neutrality policy in countries that require it. Determining these costs, along with the likelihood of each country within the EU preferring net neutrality, will allow for more concrete conclusions regarding the ideal policy decisions for the EC.

3.3.2 U.S.A

The US has a different political and regulatory setting compared to the EU and Norway. Companies are very litigious and the legalities of any legislation or regulation are decided in the courts (Kushnick, 2014). An earlier ruling has led to the FCC reclassifying the broadband access market under 'Title II' and this is sure to be challenged in the courts (Kushnick, 2014; Mashables, 2015). Given the existence of throttling and blocking behaviour, it implies that all else held equal, regulatory oversight should be stricter in order to prevent this welfare harming behaviour from occurring (Ehrenfreund, 2014). These behaviours are welfare harming, and while not directly considered in the welfare equations, the first result of Economides and Hermalin (2012) shows that these practices damage welfare prevention would yield a welfare improvement. The US also has no compulsory unbundling in place, so the investment incentives are not lowered as much as in other countries. Which means the reduction in investment incentives for ISPs are not exasperated by unbundling policy leads to a lower reduction from regulation overall. Due to these factors, with other market conditions held equal, the US is more likely to favour a stronger net neutrality regime.

3.3.3 Norway

Norway has a unique regulatory approach, as there is a substantial amount of cooperation and collaboration between the regulator, ISPs and CPs. Norway has no documented cases of throttling or blocking and the industry has historically been extremely compliant with regulators' decisions. Norway is also one of the only countries in the world to have successfully implemented compulsory unbundling and is planning on applying the same policy to the next generation network of fibre optics. This policy will have a negative effect on investments in next generation networks, which will compound the effect on investment if net neutrality is implemented. While some major ISPs, such as Telenor, object to NKOM's position on net neutrality, they still comply with their directives. As such, the optimal policy regarding net neutrality in Norway will depend on the consumer surplus, and the profitability of content providers. Total welfare is certainly aided by the lack of anticompetitive practices, and optimal regulation may or may not allow for paid prioritization.

3.3.4 Optimal policy comparisons

As discussed in the above sections, the optimal policy for each country depends crucially on the profits of the ISP per content exchanged, relative to the consumer surplus of the exchange. This warrants empirical investigation to determine the relative values in each individual market, in order to make more concrete recommendations. What can be said is that both the consumer surplus, and the profit shares will be heavily dependent on the degree of competition within each market. Ideally, further analysis would consist of not only empirical studies determining these two crucial variables, but also determining the relative welfare losses and prevalence of anti competitive behaviour in each country, along with the associated costs of regulating the industry. However analysis of this degree of specificity is not only beyond the scope of this thesis, but also overly specified given the assumptions and limitations of this model and this field of literature discussed in section 3.1.2 and 3.1.3, respectively.

The conclusions that can be drawn from this analysis must be tempered with the above caveats, but will still show interesting insights. It is worth noting that although I have focused on incorporating compulsory unbundling into the discussion of the net neutrality policy decision, it is possible that other regulations or policies have additional effects that warrant examination. If I for a moment assume that the consumer surplus and profit margin, per unit of content, are equal across the US, EU and Norway, it allows for interesting conclusions as a result of key factors noted in each of these markets. The US has blocking and throttling behaviour occurring and has no compulsory unbundling policy in place for the fibre optic next generation network. Europe has observed blocking and throttling occurring, and the European Commission has put in place compulsory unbundling legislation and directives to its members. Norway, in contrast, has not observed blocking or throttling, and has compulsory unbundling policies in place and intend to implement them on the next generation networks. This leads to the conclusion that under this assumption, the US is the most likely to have net neutrality as its optimal policy, while the EU is less likely and Norway is the least likely.

4 Conclusion

This thesis has focused on the issue of net neutrality. Initially I defined the issue and framed its political and practical consequences for Norway, Europe and the US. These countries have important differences, with Europe and the US both having cases of throttling and blocking. In the US, telecommunications companies have an extremely litigious history. The original net neutrality doctrine was overturned in the legal system, allowing blocking and throttling to occur, and the major telecommunication companies promise that the most recent legislation will be similarly challenged. The European Commission takes a very pro neutrality position and has passed legislation allowing reasonable network management, but forbidding both blocking and throttling. In contrast, Norway uses a coregulatory approach and has issued directives that preclude blocking and throttling. There are no documented cases of it occurring within their networks.

The results of Economides and Hermalin's model show that blocking and throttling are welfare harming. They also find that paid prioritization welfare effects with fixed bandwidth depend on whether the elasticity of demand changes across content providers. In a dynamic setting, they also find that ISP investment is harmed by net neutrality. When accounting for ISP investment with perfect price discrimination, the welfare results are ambiguous and depend on the profit share per unit of content, relative to the consumer surplus per unit of content. Thus, whether net neutrality is welfare optimal depends on the relative values for each country. This opens the possibility that net neutrality may be optimal in some countries but not others. Different regulatory approaches, including prevalence of blocking and throttling and whether compulsory unbundling exists, are relevant for determining which countries are more likely to have optimal net neutral policies.

Future research should be focused on dynamic effects and the role investment has to play while incorporating competition within the ISP industry, the effects of existing regulations (compulsory unbundling in Norway and the UK, for example), the minimum investment required for next generation networks, as well as imperfect price discrimination for both the CPs and the HHs. If consumer surplus and profit shares are held constant, it is more likely that the US maximises welfare with strong net neutrality while it is less likely that the same is true in Norway.

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Appendix

Explicit calculations with separable preference function

This is a more formal calculation of the result from section 2.2.3, I will start by extending the assumptions about the preference function, returning to equation (12)

$$t_n = \frac{1}{B_n}\omega(p^*)\int\limits_{Qn} \alpha(t_n, \theta) dF(\theta) \tag{12}$$

Suppose that the preference function is multiplicatively separable and can be decomposed as below

$$\alpha(t, \theta) = \gamma(\tau)v(\theta), \tag{22}$$

also assume both $\gamma(\tau)$ and $v(\theta)$ are strictly positive and $\gamma(\tau)$ is a decreasing function whereas $v(\theta)$ is an increasing function. Both are measurable and continuous functions. Define a function $g(t)$, which contains $\gamma(\tau)$ and thus derives its properties from it. Assume $g(t)$ is convex, however this assumption does not constitute a large departure from the embedded assumptions, given the composition of $g(t)$ it will be convex over large portions of its range, if not its entire range. All of these are formally shown below:

$$\gamma(\tau) > 0, v(\theta) > 0 \tag{A1}$$

$$\gamma'(\tau) < 0, v'(\theta) > 0 \tag{A2}$$

$$g(t) = \frac{t}{\gamma(\tau)}, g(t) > 0, g'(t) > 0 \tag{A3}$$

$$g^{-1}(t) > 0\, , g^{-1\prime}(t) > 0 \tag{A4}$$

$$g''(t) > 0 \tag{A5}$$

To begin solving for the optimal transmission times, first substitute (22) into (8).

$$t_n = \frac{1}{B_n}\omega(p^*)\int\limits_{Qn} \gamma(\tau)v(\theta) dF(\theta) \tag{A6}$$

As $\gamma(\tau)$ does not vary across the subset it can be extracted from the integral.

$$\frac{t_n}{\gamma(\tau)} = \frac{1}{B_n}\omega(p^*)\int_{Qn} v(\theta)dF(\theta) \tag{A7}$$

Substituting in $g(t)$ on the left hand side and inverting the equation leads to

$$t_n = g^{-1}\left[\frac{\omega(p^*)}{B_n}\int_{Qn} v(\theta)dF(\theta)\right] \tag{A8}$$

In the case of a net neutral regime the equilibrium time is

$$t^* = g^{-1}\left[\frac{\omega(p^*)}{B}\int_{\underline{\theta}}^{\overline{\theta}} v(\theta)dF(\theta)\right] \tag{A9}$$

As B is now evenly distributed between all content, and no content is tiered or excluded. This leads to the next result.

Economides & Hermalin (2012) state in their Proposition 4 states that if equation (22) is an appropriate separation of the preference function, and if $g(t)$ is a convex function, then a net neutral regime is strictly welfare superior to any non-neutral regime that excludes a non-zero amount of content. It is also strictly welfare superior to any regime where different transmission times for different content providers arise. A net neutral regime is weakly welfare superior to any non-neutral regime.

$$W_{neutral} \geq W_{non\,neutral}$$

$$W_{neutral}(Q_n, t^*) > W_{non\,neutral}(Q_m, t)$$

if $Q_n > Q_m$ or if $t^* \neq$ t for any group of content providers.

It is worth noting that proposition 4 follows directly from proposition 3, as equation (22) implicitly states that

$$\frac{d\varepsilon(\tau,\theta)}{d\theta} = 0$$

Deriving the profit function of the ISP

Calculations from section 2.2.1

The profit function for ISPs in this setup can be written as

$$Profit(ISP) = \left(1 - F(\theta_l)\right)s_l + \left(1 - F(\theta_h)\right)(s_h - s_l) + \eta \tag{30}$$

In order to determine the effects of neutral and non-neutral pricing, s_l, s_h and η must be solved in order to determine a more explicit profit function. Using the earlier assumption from equation (22) about separability of the preference function and assuming they are both differentiable. The following notations are useful for simplifying the equations

$$I(\theta_1, \theta_2) = \int_{\theta_1}^{\theta_2} v(\theta)dF(\theta) \tag{31}$$

$$G(z) = g^{-1}(z) \tag{32}$$

To begin solving for s_h, start with equation (12)

$$t_l = \omega(p^*) \int_{\theta l}^{\theta_h} v(\theta)y(t)dF(\theta)$$

Substitution of (31) and (32) leads to

$$t_l = G\left[\frac{\omega(p^*)I(\theta_l, \theta_h)}{B_l}\right], \tag{A10}$$

using equation (29) and substituting into (A10) it follows that

$$s_l = \pi v(\theta_l)y\left(G\left[\frac{\omega(p^*)I(\theta_l, \theta_h)}{B_l}\right]\right), \tag{A11}$$

making an equivalent calculation for the high type gives an equivalent expression

$$s_h = \pi v(\theta_h)y\left(G\left[\frac{\omega(p^*)I(\theta_h, \bar{\theta})}{B_h}\right]\right). \tag{A12}$$

Now to solve for η, which is done using (28a)

$$\eta = \sigma y(t)\left[\int_{\theta_l}^{\theta_h} v(\theta)dF(\theta) + \int_{\theta_h}^{\bar{\theta}} v(\theta)dF(\theta)\right], \tag{A13}$$

substituting using equations (31) and (22c) leads to the intermediate equation below

$$\eta = \sigma\left[\frac{t_l}{g(t)}I(\theta_l,\theta_h) + \frac{t_h}{g(t)}I(\theta_h,\bar{\theta})\right]. \tag{A14}$$

Substituting in equation (33)

$$\eta = \sigma\left[\frac{G(\frac{\omega(p^*)I(\theta_l,\theta_h)}{B_l})I(\theta_l,\theta_h)}{g(t)} + \frac{G(\frac{\omega(p^*)I(\theta_h,\bar{\theta})}{B_h})I(\theta_h,\bar{\theta})}{g(t)}\right], \tag{A15}$$

and finally substituting in equation (22c) and rearranging.

$$\eta = \sigma\left[\frac{B_l G(\frac{\omega(p^*)I(\theta_l,\theta_h)}{B_l})}{\omega(p^*)} + \frac{B_h G(\frac{\omega(p^*)I(\theta_h,\bar{\theta})}{B_h})}{\omega(p^*)}\right] \tag{A16}$$

An explicit ISP profit function can now be shown by taking equation (30) and substituting in equations (34), (35) and (36) respectively to find

$$\begin{aligned} Profit(ISP) = {} & \big(1 - F(\theta_l)\big)\pi v(\theta_l)y\left(G\left[\frac{\omega(p^*)I(\theta_l,\theta_h)}{B_l}\right]\right) \\ & + \big(1 - F(\theta_h)\big)\pi v(\theta_h)y\left(G\left[\frac{\omega(p^*)I(\theta_h,\bar{\theta})}{B_h}\right]\right) \\ & - \pi v(\theta_l)y\left(G\left[\frac{\omega(p^*)I(\theta_l,\theta_h)}{B_l}\right]\right)) \\ & + \left[\frac{B_l G(\frac{\omega(p^*)I(\theta_l,\theta_h)}{B_l})}{\omega(p^*)} + \frac{B_h G(\frac{\omega(p^*)I(\theta_h,\bar{\theta})}{B_h})}{\omega(p^*)}\right] \end{aligned} \tag{33}$$